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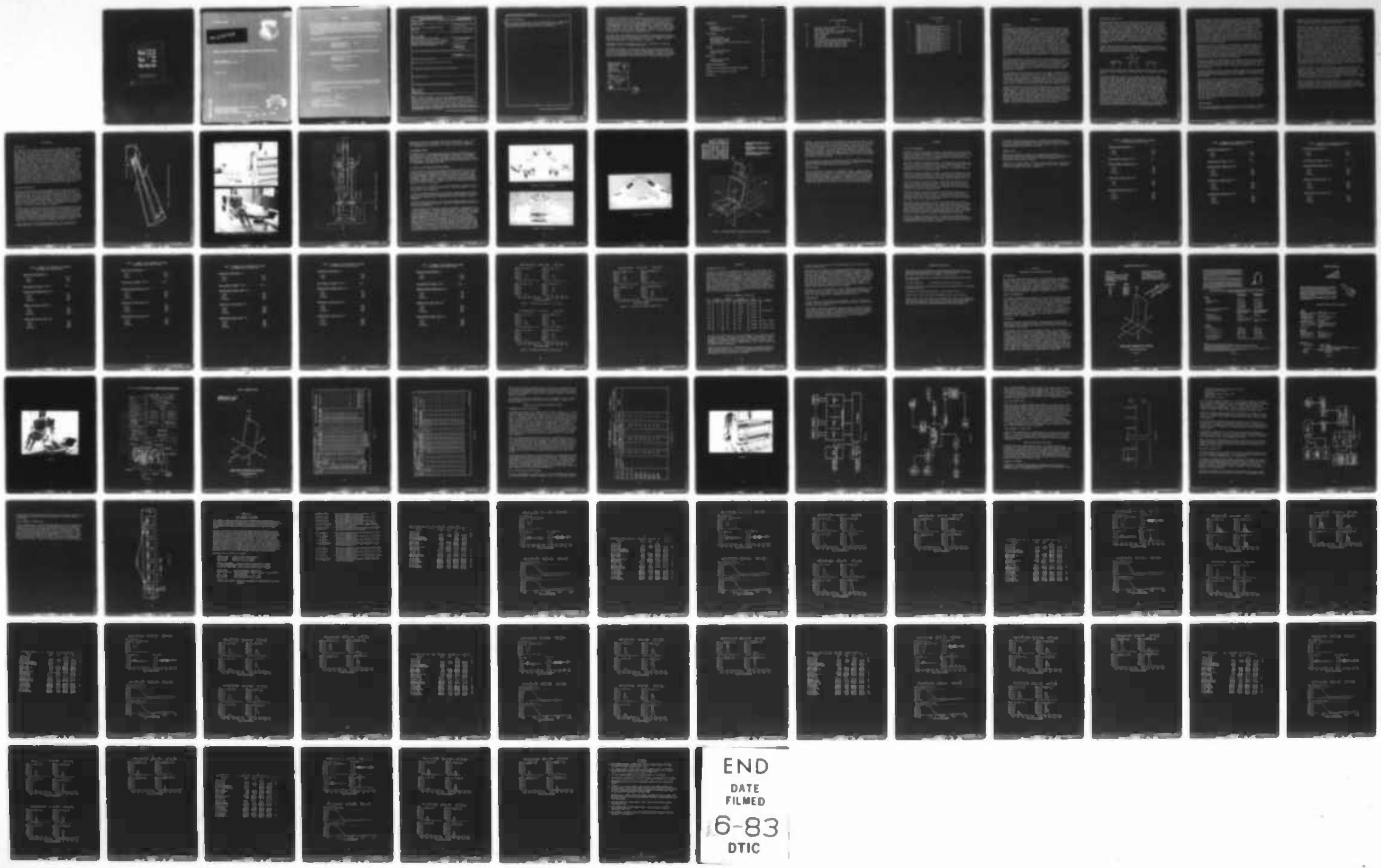

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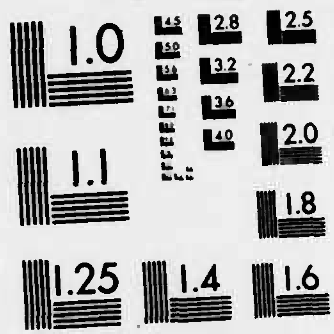

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IMPACT TESTS OF HBU-X AUTOMATIC LAP BELT PROTOTYPES

JAMES W. BRINKLEY
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SEPTEMBER 1982

AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
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AFAMRL-TR-82-66

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Henning E. von Gierke

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Director
Biodynamics and Bioengineering Division
Air Force Aerospace Medical Research Laboratory

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Impact tests were conducted to evaluate three preproduction HBU-X automatic lap belts of different designs developed by three competing contractors. Eight impact tests were performed as part of a program to select a lap belt to replace all HBU and MA-5/6 series lap belts currently in service. Each lap belt was to be tested at progressively higher G levels (32 G, 38 G, and 40 G) and velocities (up to 106 ft/sec) until failure occurred or until the 40 G test level was achieved without failure. Each of the lap belts failed structurally or exceeded

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the belt adjuster slippage limit (1/2") during the impact tests. Further tests of a single buckle that did not structurally fail in the test series and adjusters that passed the slippage criteria are recommended.

PREFACE

This report was prepared by the Biomechanical Protection Branch, Biodynamics and Bioengineering Division of the Air Force Aerospace Medical Research Laboratory. The testing and evaluation effort that is described within this report was accomplished as directed by Program Management Plan No. 105 ASD/AES, Air Force Program Management Directive No. R-P2030/64706F/412A as amended by PMDR-P2030 (11) 64706F/412A, dated 10 March 1980, and AFSC Program Directive (AFSC Form 56) 64706-80-92 dated 18 March 1980. CMSgt Donald L. Wennen was the Program Manager and Mr. Robert M. Dixon was the Program Engineer for the Life Support System Program Office of the Aeronautical Systems Division.

The impact facilities, data acquisition equipment, and data processing system were operated by the Scientific Services Division of the Dynalectron Corporation under Air Force contract F33615-79-C-0523. Mr. Harold F. Boedeker was the Engineering Supervisor for the Dynalectron Corporation.

Photographic data and documentation services were provided by the Technical Photographic Division of the 4950th Test Wing.

The authors are grateful to the many personnel of the Biomechanical Protection Branch who participated in the planning, accomplishment, and documentation of this test and evaluation effort. Special acknowledgment is given to Mr. Herman Engel of the Crew Equipment and Human Factors Division, Directorate of Equipment Engineering, Aeronautical Systems Division, for his technical consultation.

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INTRODUCTION

BACKGROUND

Operational malfunctions caused by design deficiencies in MA-5/-6 series lap belts prompted a replacement effort. That effort, initiated in 1965, resulted in the development and operational issue of the HBU series automatic lap belts in 1970. Inherent design deficiencies in the HBU belts, that were identified in operational testing and throughout its operational life, have proven difficult to correct. After many years of testing and several attempts to correct the operational and safety problems associated with the HBU series belts, Air Training Command rejected use of the HBU belts and resumed use of the MA-5/6 series belts although fully recognizing their design deficiencies. MAJCOM representatives to the 1979 World Wide Life Support Conference reported that aircrew confidence in both types of belts was seriously declining. This lack of confidence was considered to be a potential cause of delayed ejection decisions which might reduce chances of successful ejection. The resultant action was initiation of the HBU-X Lap Belt Program to replace all existing HBU and MA-5/-6 series lap belts. The objective of this program was to eliminate all identified deficiencies in the existing belts which cause injury or fatalities during ejection.

This report describes the results of a series of eight impact tests conducted on three preproduction HBU-X automatic opening, lap belts of different design developed by three competing contractors. These tests were performed in accordance with the HBU-X Lap Belt Test Plan, dated 8 Oct 81. The tests were conducted under the auspices of the Life Support System Program Office (ASD/AES) of the Aeronautical Systems Division of the Air Force Systems Command, Wright-Patterson Air Force Base.

The test program that was conducted to evaluate each HBU-X prototype included developmental as well as qualification tests. Developmental testing was performed on the HBU-X components and assembly by each contractor. Tests were also accomplished by the contractor to demonstrate that the design and construction of the HBU-X prototype would meet the requirements of the development specifications. Test requirements included engineering development tests, system qualification tests, reliability and maintainability tests, and laboratory tests.

Final qualification tests were performed by the Air Force. The belts were subjected to a series of ejection seat tests accomplished by the 6585 Test Group, Holloman AFB, N.M. Impact testing was performed by the Biomechanical Protection Branch, AFAMRL, Air Force Systems Command. Initial Operational Test and Evaluation (IOT&E) was defined and conducted under the direction of Tactical Air Command with coordination through the Implementing Command (AFSC) and a Test Plan Working Group. Participating commands coordinated requirements for test articles, test procedures, and reporting responsibilities with the Tactical Air Command. Participating commands provided the required resources to conduct IOT&E to include aircraft, personnel, maintenance, and facilities.

IMPORTANCE OF DYNAMIC TESTS

Restraint systems used in ejection seats must provide protection for the seat occupant under a wide spectrum of acceleration conditions. The acceleration conditions vary in terms of direction, magnitude, rate of onset, and energy level. The design of the restraint systems and their components are sensitive to each of these factors. For example, a webbing adjuster may prevent webbing slippage under steady state loads but will slip under dynamic load conditions. Furthermore, webbing materials commonly used in USAF restraint systems will fail at different force levels depending upon the rate of application of the load and the energy level. Recent operational mishaps involving restraint system failures have focused additional attention on the methods used to evaluate the adequacy of restraint systems. It is especially important that the methods that are used adequately simulate the dynamic characteristics of the operational conditions.

Ejection seats and their restraint systems must meet the acceleration and loading conditions described in MIL-A-008865A(USAF), rigidity, and MIL-S-9479B (USAF), the ejection seat specification. MIL-A-008865A specifies that ejection seats should be designed for the crash loads listed below.

TABLE 1

SEAT CRASH LOADS

Longitudinal		Vertical		Lateral	
Forward	Aft	Down	Up	Left	Right
40	7	25	10	14	14

The loads that are specified are minimum ultimate load factors that are to be multiplied times the combination of occupant weight plus equipment shown in AFSC DH 2-1.

MIL-S-9479B (USAF) also describes the ultimate loads for the seat system including the restraint system. Three restraint subsystem load conditions are specified: 8,600 lb forward, 8,600 lb 20° to each side of forward, and 1,750 lb downward applied through the occupant center of gravity. The seat system must carry these loads plus 40 times the seat weight forward and 20° to each side of forward, respectively, through the combined occupant and seat system center of gravity, and 4,300 lb plus 25 times the seat system weight downward through the occupant and seat system combination center of gravity. MIL-S-9479B (USAF) further specifies that the seat system must withstand shock test conditions in accordance with method 516, procedures I and III with a shock pulse in accordance with Figure 515-1 (now labeled Figure 516.2-1 and -2), amplitude a and time duration c, of MIL-STD-810. The most severe shock pulse described has a peak acceleration value of 40 G with a nominal duration of 0.011 sec. Unfortunately, this pulse represents a velocity change of only 7.1 ft/sec, which can be produced by a drop height of little more than 9 inches. It is clearly not a test that will adequately evaluate a restraint system intended to protect a seat occupant under high velocity aircraft crash or emergency escape conditions.

MIL-S-9479B (USAF) is usually interpreted to also require a restraint system that will withstand the loads applied throughout the entire escape sequence at ejection velocities up to and including 600 knots equivalent airspeed (KEAS). Unfortunately, this logical interpretation is sometimes confounded by an erroneous interpretation that the maximum restraint harness loads that will be experienced are associated with the acceleration limit conditions (maximum of 35 G in the -X axis) specified in Figures 4 through 8 of MIL-S-9479B (USAF). This second interpretation is incorrect since it assumes that the escape accelerations will always be no more than the limit conditions. In practice, this has not been the case. Therefore, the restraint system must be designed to withstand the actual acceleration conditions associated with 600 KEAS escape. The accelerations are frequently higher due to the lack of directional stability of the seat and the occurrence of high transient loads such as the opening shock associated with a drogue parachute.

Taking each of these requirements into consideration, it appears that the 40 G minimum ultimate load is a reasonable test condition to meet the forward load conditions that would be expected under either aircraft crash or emergency escape conditions. However, in view of both the operational conditions which have led to catastrophic failures of restraint systems during the ejection sequence and the experience gained from dynamic tests of restraint systems, it is important that the loads be applied dynamically to uncover failure modes that would not become apparent under steady state loads.

Specification number 412A-07878-55016, the development specification for HBU-X lap belts, describes two types of impact tests. These are shock up to 400 $\pm$40 G (3 millisecond pulse duration) along any axis and crash loads of 40 G. The impact tests that are described in this report were accomplished to provide the 40 G crash loads.

The HBU-X specification does not provide a detailed description of the 40 G test conditions; therefore, the test conditions were developed in consultation with the Life Support System Program Office and other members of the HBU-X Test Plan Working Group.

The acceleration profile was determined on the basis of previous estimates of fighter aircraft crash velocities and crash test conditions (Preston and Moser, 1956), dynamic testing recommendations of the Air Force Flight Dynamics Laboratory (Peterson, 1969), and the available acceleration profile control metering pins of the AFAMRL Impulse Accelerator Facility. It was decided that the 40 G acceleration profile would be a triangular shape of 0.1 to 0.12 sec duration with a velocity change of at least 64 ft/sec. Available metering pins then dictated that the profile would be 0.12 sec in duration, peak at 40 G in 0.07 sec, and achieve a maximum velocity of 106 ft/sec. The velocity change of the test profile exceeds the minimum velocity, but this is desirable since it covers a larger range of potential aircraft crash velocities and emergency escape conditions.

TESTING APPROACH

The tests were accomplished to demonstrate the structural integrity of the HBU-X lap belts when subjected to an acceleration of 40 G. The acceleration pulse

duration was 125 milliseconds with a velocity change of 104 to 106 ft/sec. This acceleration profile provided a high-energy impact condition to approximate aircraft crash or ejection seat acceleration conditions.

Prior to testing the HBU-X lap belts, a series of tests were accomplished to establish the impact facility operating parameters necessary to achieve the velocity, duration, and peak G impact profile specified in the test plan. The initial tests of this series were conducted without a dummy and restraint harness. To verify the 40 G impact profile, the final test in this series, test 1968, was accomplished with the dummy restrained in the seat fixture using a modified HBU-2 lap belt and double shoulder harness. Test 1968 resulted in complete failure of the restraint harness. Test 1968 occurred as programmed and all impact facility systems functioned normally. This test was scheduled to produce a peak acceleration of 40 G, with a velocity change of 106 ft/sec. The measured impact sled acceleration was 44.1 G with a velocity change of 99.7 ft/sec. The higher acceleration is attributed to the restraint failure and the reduction of the sled/payload mass as the dummy separated from the sled. A review of the high speed films and lap belt load data of test 1968 revealed that the lap belt webbing material failed at its point of attachment to the belt buckle, preceding and precipitating total restraint harness failure, at loads well below the peak lap belts loads expected from a nominal 40 G impact exposure. The plan, prior to test 1968, was to conduct all tests at the 40 G impact level. As a result of this incident, a modification of the test plan was proposed and approved by ASD/AES. The modification provided a method to collect data to enable comparisons between the HBU-X lap belts at progressively higher acceleration levels. Each of the prototype lap belts would be exposed initially at the 32 G, then 38 G, and finally at the 40 G level.

The dummies used for this program were Alderson Research Laboratories, Inc., type F-95 and C-95. These dummies were selected because they were readily available at AFAMRL in numbers sufficient to accomplish the test program. These dummies were designed to represent a 95th percentile weight adult male. Although these dummies do not realistically reproduce human response to impact, the weight and weight distribution were considered to be adequate for -Gx impact structural adequacy testing of the HBU-X lap belts.

Due to the sensitive nature of contractor competition in the HBU-X lap belt program, contractors and their representatives were restricted from the test area during testing. In addition contractors were not permitted to have access to any data from the tests. Prior to the testing of HBU-X lap belts all branch personnel and the on site contractor were briefed on this policy.

TEST METHODS

IMPACT FACILITY

The AFAMRL Horizontal Impulse Acceleration Facility shown in Figure 1, was used for all tests. The Horizontal Impulse Accelerator actuator, test sled, and test seat are shown in Figures 2 and 3. Figure 4 is a cross section view of the actuator. The actuator produces forward thrust through differential gas pressures acting on opposite faces of a thrust piston in a closed cylinder. The cylinder is divided by an orifice plate into a rear or load chamber and a front or set chamber. Prior to firing, a low gas pressure (relative to the rear chamber pressure) forces the thrust piston against a seal ring on the orifice plate. The full area of the front of the thrust piston is exposed to the high pressure in the rear chamber. The system is stable in this condition as the net force on the piston is acting rearward so as to maintain the seal. At firing, high pressure gas is introduced between the orifice plate and the rear of the thrust piston upsetting the seal. At this point the full area of the rear of the thrust piston is exposed to the high pressure gas in the rear chamber producing a large net forward force on the thrust column and sled combination. By controlling the manner in which the gas is metered through the orifice into the thrust chamber, the stroke length and the initial pressures, the resulting force and the acceleration imparted can be altered and controlled. After the initial acceleration, the test portion, the sled is decelerated along the track rails by pneumatic brakes at a deceleration level much lower than the impact level.

DATA ACQUISITION SYSTEM

Both data acquisition and processing requirements were satisfied by utilizing the Automatic Data Acquisition System (ADACS), which has the capability of sampling 48 channels at a rate of 1000 samples/second/channel. For this test program, data were taken using 14 channels. The on board portion of the ADACS amplifies, filters, and encodes the analog data samples from all channels into a digital format (pulse code modulated) which is then transmitted via an umbilical cable to a word formatter. The word formatter reformats the serial data into parallel data which are then routed to a PDP-11/34 computer for storage and analysis. For details on this system, see Appendix A.

Electronic data collected during the tests included sled acceleration and velocity, and harness loads. Detailed descriptions of the instrumentation, electronic data processing equipment, mounting procedures, and calibration techniques are provided within Appendix A. Sled acceleration was measured using three miniature, piezoresistive accelerometers mounted to the structure of the sled. Velocity was computed from displacement data collected during the impact phase of the tests. The test fixture was instrumented to measure the inertial forces reacted into the restraint system by the dummy using triaxial load cells.

A video camera was also used to document the tests. This camera and the recorder used with it are capable of recording motion at a rate of 120

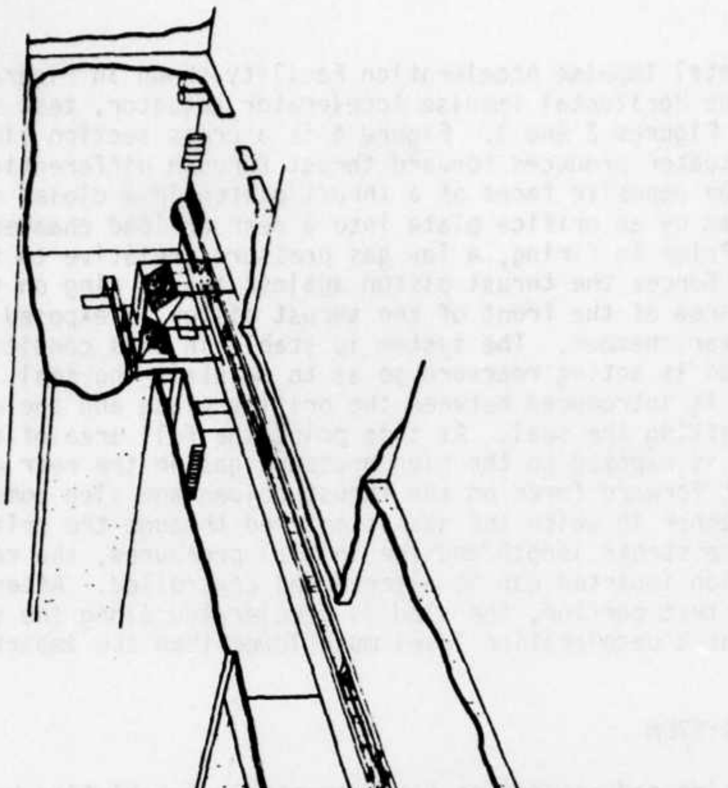


FIGURE 1. HORIZONTAL IMPULSE ACCELERATION FACILITY

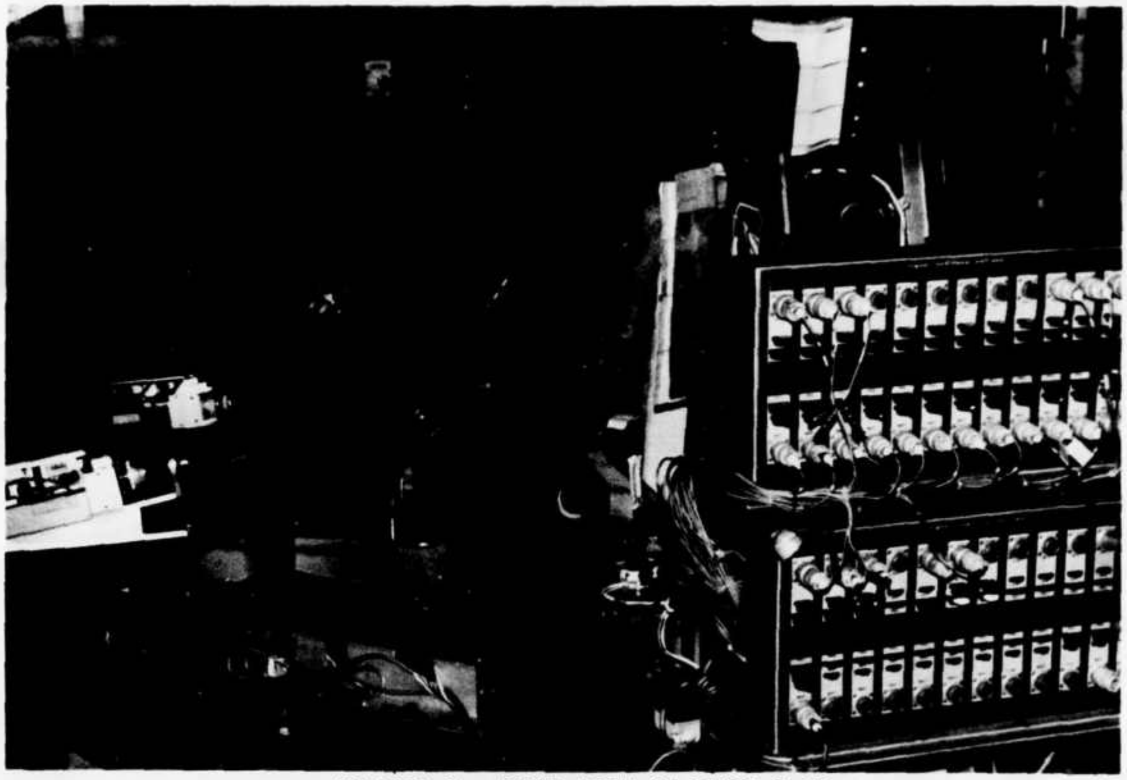


FIGURE 2. REAR VIEW OF TEST SLED

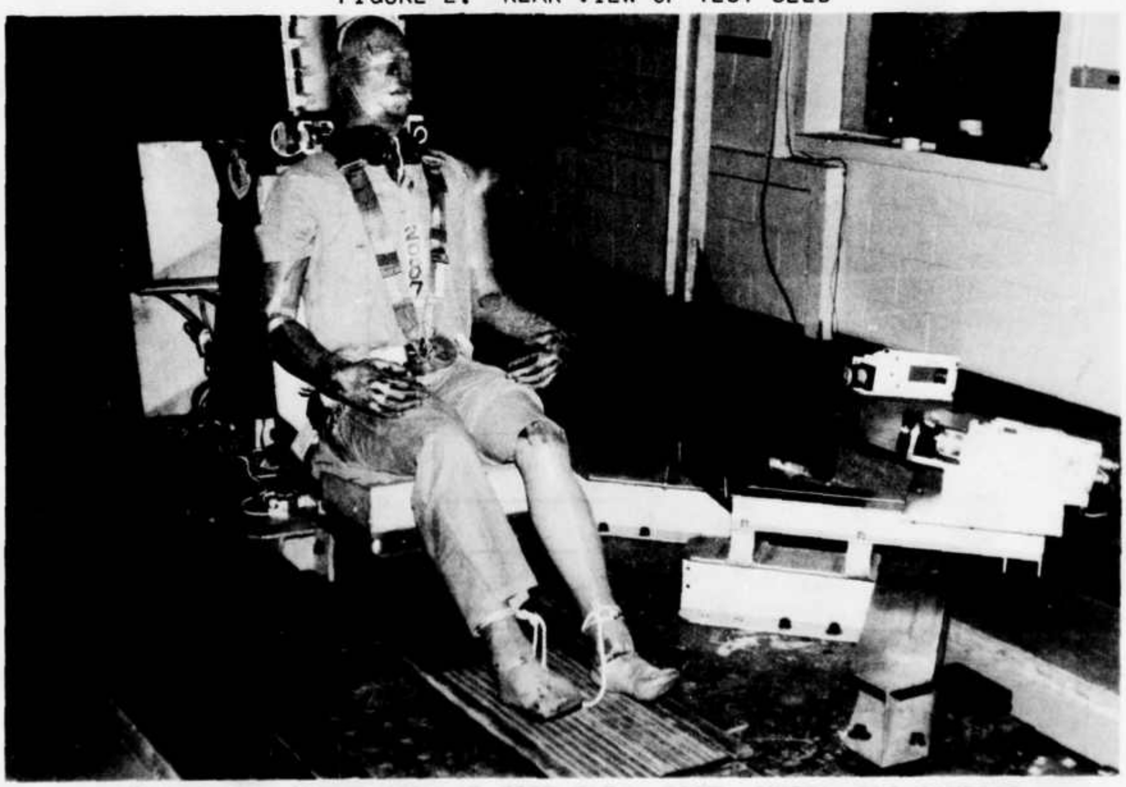


FIGURE 3. FRONT VIEW OF TEST SLED, SEAT, DUMMY, AND CAMERAS

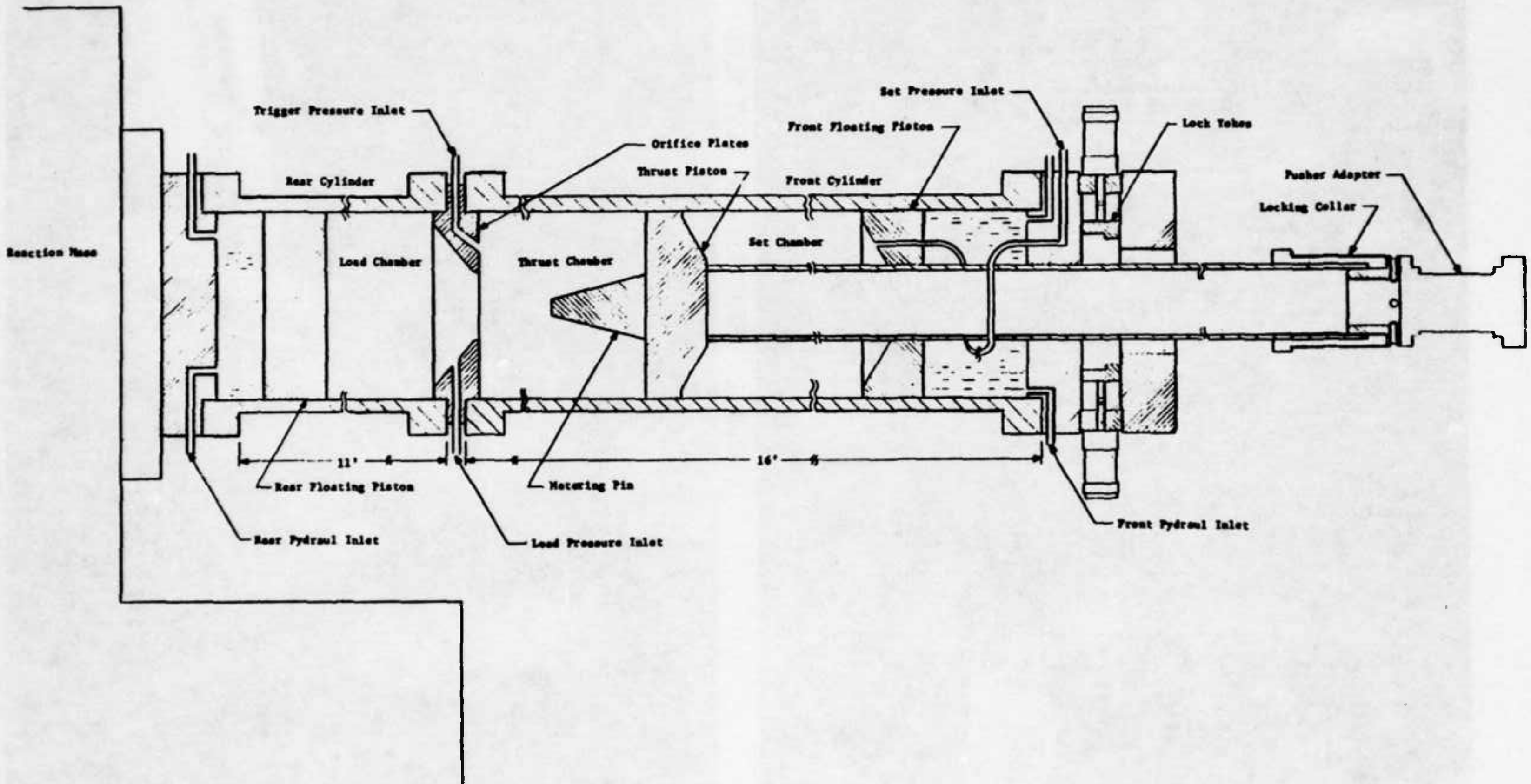


FIGURE 4. CROSS SECTION VIEW OF THE ACTUATOR

frames/sec with an effective shutter speed of 10 microseconds or less. Use of this system allowed the investigators to evaluate the lap belt response to impact immediately after each test. This system is described in Appendix A.

ANTHROPOMORPHIC DUMMY

The dummies used for this program were Alderson Research Laboratories, Inc., type F-95 and C-95. These dummies are designed to represent a 95th percentile adult male and are commonly used for USAF ejection seat tests. The dummies weighed 210 lbs. Prior to testing, the dummy's joints were adjusted to a nominal one G value in accordance with Federal Motor Vehicle Safety Standard No. 208 (U.S. Department of Transportation, 1972).

TEST ARTICLES, TEST PREPARATIONS AND PROCEDURES

The HBU-X lap belt is an automatic opening, adjustable safety belt for aircraft ejection seats. The automatic opening feature of the belt is gas activated. The buckle assembly incorporates a mechanism to provide manual opening. The buckle also provides a connection for a gold key used for automatic parachute deployment. The belt consists of two fabric web straps, two strap adjusters, and seat attachment hardware. Examples of the HBU-X Lap Belts manufactured by Stencel Aero Engineering, Frost Engineering, and H. Koch and Sons; are shown in Figures 5, 6, and 7, respectively.

The Stencel lap belts consisted of 1 3/4 inch wide polyester webbing, two East/West adjusters, and a Stencel lap belt buckle, featuring a depress-and-lift-to-release manual release mechanism.

The Frost lap belts consisted of 1 3/4 inch wide polyester webbing, two Frost adjusters, and a Frost lap belt buckle, featuring a squeeze-and-lift-to-release manual release mechanism and an independent gas pressure automatic release mechanism.

The Koch lap belts consisted of 1 3/4 inch wide polyester webbing, two Koch adjusters, and a Koch lap belt buckle, featuring a squeeze-and-rotate-to-release manual release mechanism.

All HBU-X lap belts were tested as delivered by ASD/AES. Each component of the restraint harness, i.e., lap belt, shoulder harness, crotch (negative G) strap, and associated hardware, received only one exposure to $-G_x$ impact. The shoulder harness was an MB-6 harness (MIL-H-5364D) constructed of 1 3/4 inch wide Type I polyester webbing (MIL-W-25361C). The crotch strap (Air Force Part No. 45402-0101649-01) was also constructed of 1 3/4 inch wide Type I polyester webbing. The restraint harness attachment locations and seat dimensions are shown in Figure 8. Prior to each test the lap belt and shoulder harness were preloaded to create a force of 10 ± 2 pounds measured at each of the restraint load cells. The configuration of the test fixture, harness attachment points, and the symmetry of the restraint harness were identical for all tests. After all adjustments to the lap belts and shoulder harness were completed, each belt and shoulder harness was marked at the adjuster to allow measurement of belt

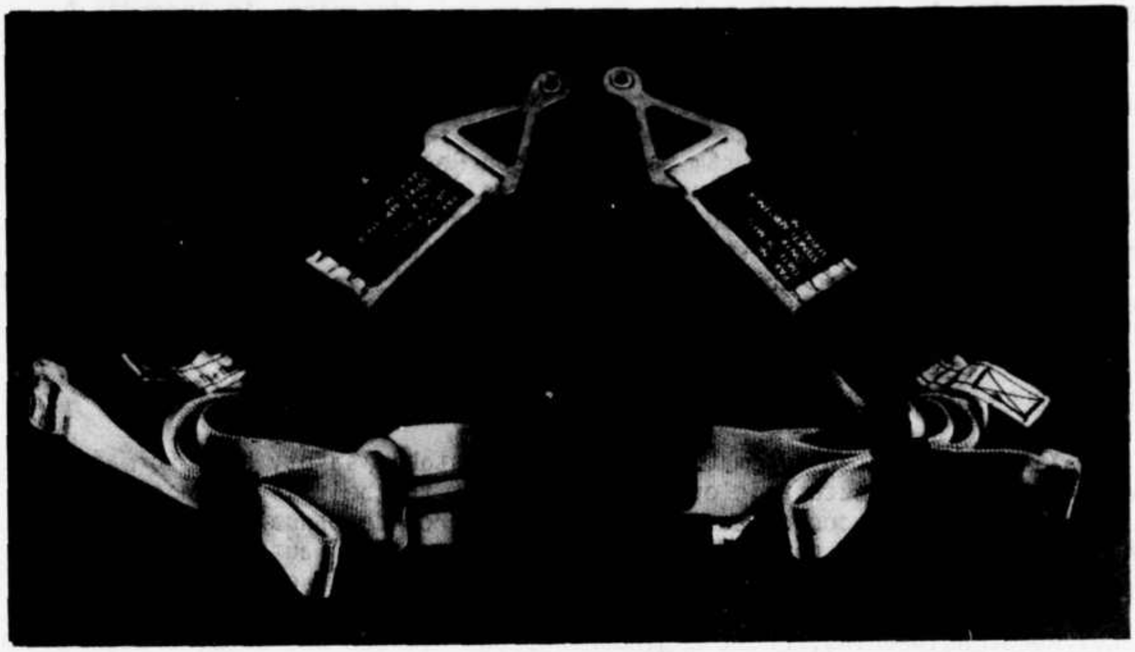


FIGURE 5. STENCEL LAP BELT

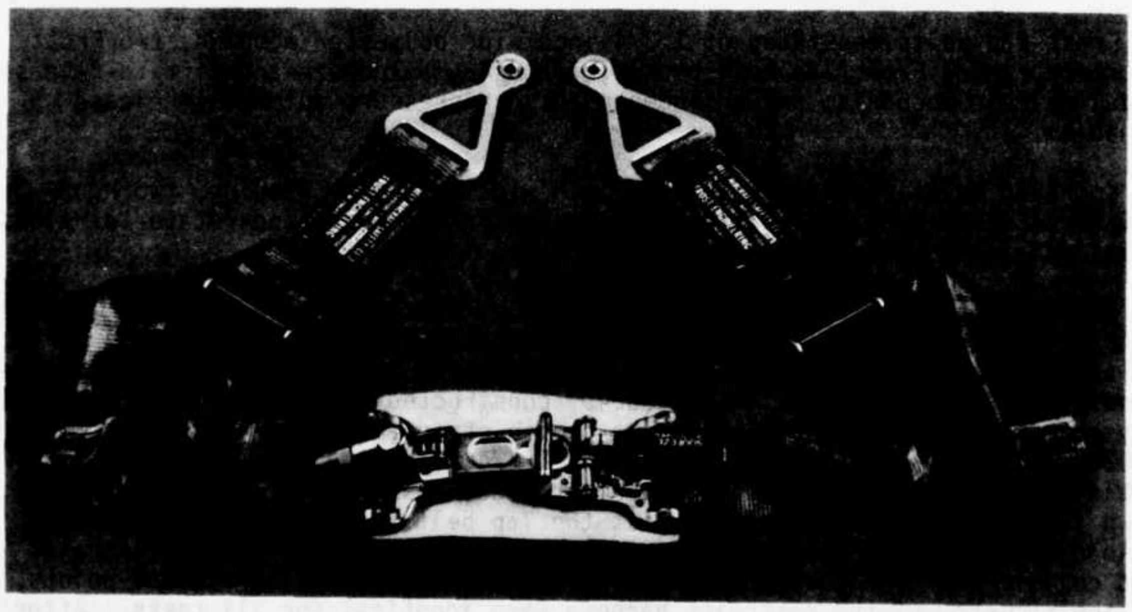


FIGURE 6. FROST LAP BELT

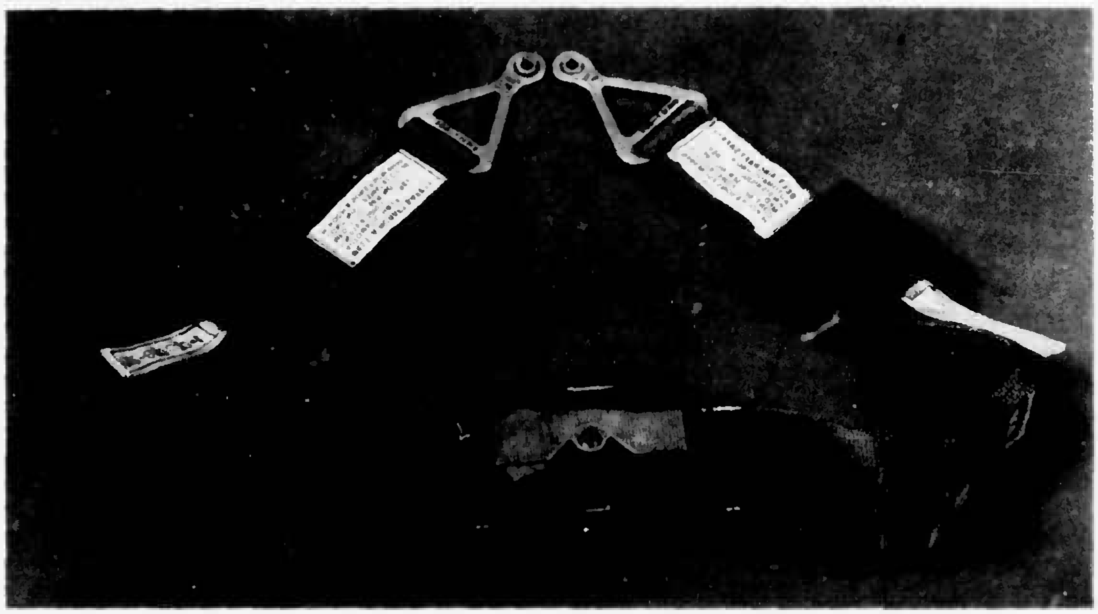


FIGURE 7. KOCH LAP BELT

	Point No.	Axis X	Inches (Centimeters) Y	Z
Center Reference	1	0	0	0
Load Cell	2	+15.00 (+38.1)	0	-1.56 (-3.96)
Triaxial Load Cell	3	0	+9.00 (+22.86)	-1.77 (-4.50)
Triaxial Load Cell	4	0	-9.00 (-22.86)	-1.77 (-4.50)
Triaxial Load Cell	5	-11.83 (-30.00)	0	+26.76 (+68.00)

LOAD CELL 2 PROVIDES A POSITIVE (+) OUTPUT VOLTAGE WHEN THE N-G STRAP IS PULLED IN THE +Z DIRECTION.

TRIAXIAL LOAD CELL 5 PROVIDES A POSITIVE (+) OUTPUT VOLTAGE FOR X, Y AND Z WHEN THE HARNESS IS PULLED IN THE +X, -Y AND -Z DIRECTIONS RESPECTIVELY.

TRIAXIAL LOAD CELLS 3, 4 PROVIDE A POSITIVE (+) OUTPUT VOLTAGE WHEN THE HARNESS IS PULLED TOWARDS THE CENTER REFERENCE.

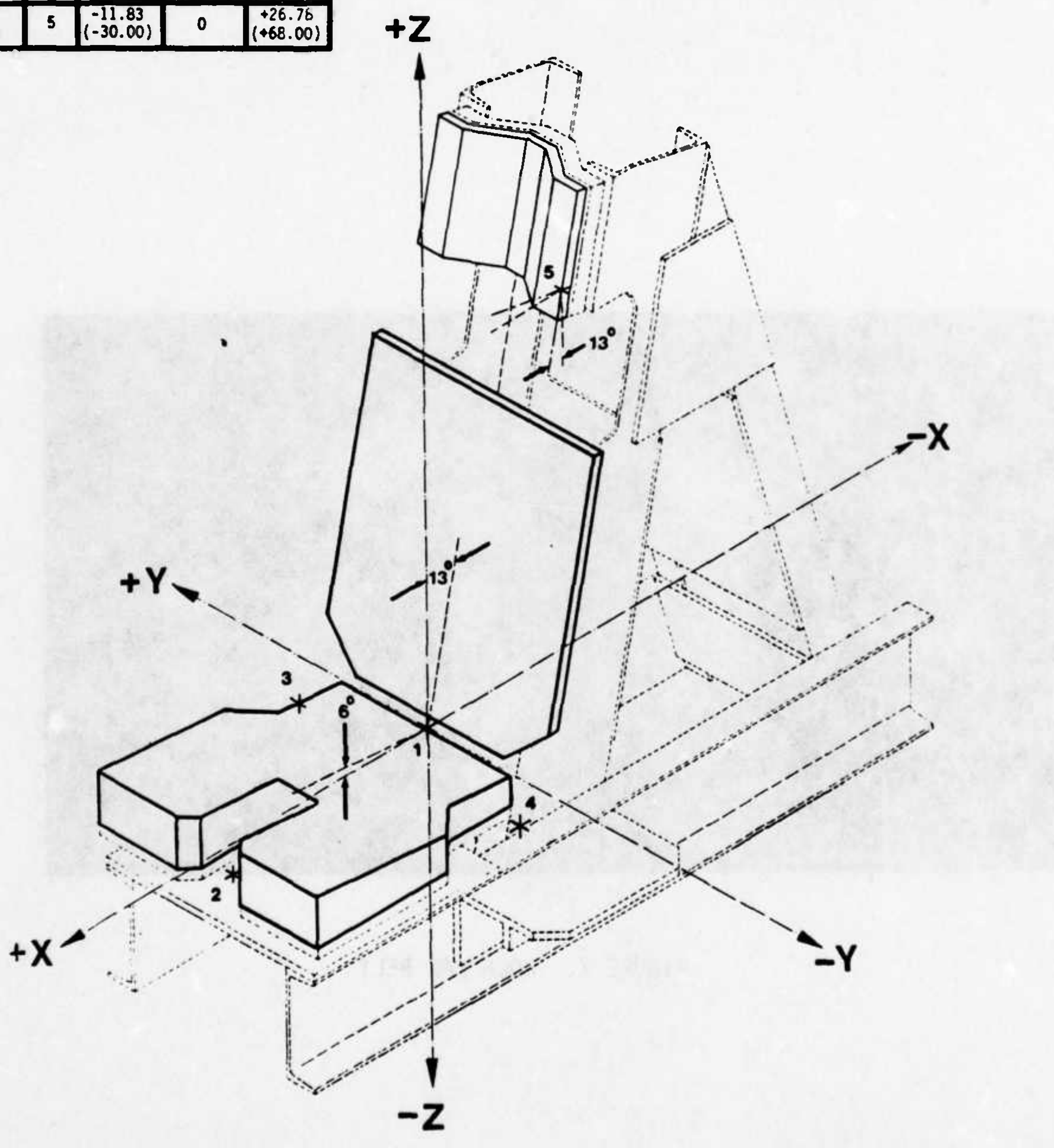


FIGURE 8. RESTRAINT HARNESS ATTACHMENT LOCATIONS & SEAT DIMENSIONS

slippage. Impact tests were to be accomplished at progressively higher G levels and velocities until failure occurred or until the 40 G test level was achieved. The first exposure was at 32 G, the second exposure at 38 G, and the final exposure at 40 G. The negative G strap was used with the restraint harness only during the 40 G impact. This test sequence was repeated for all tests of the contractor's lap belts. After each test the belt buckle was manually released by the test conductor to check for proper function. The belts were then removed from the test fixture and any belt slippage was measured. Post test photographs were taken of all test failures.

The only exception to the test sequence occurred after catastrophic failures of the Koch buckle during both the 32 G and 38 G tests. ASD/AES elected to cancel impact testing of the Koch lap belt at the 40 G level.

DATA PROCESSING

Data from each test was reduced in a standardized format. Reduced electronic data are available for review within Appendix B. Computer summaries provide relevant maxima and minima from a total of 14 recorded signals. Relevant sums and times were also computed. The sums of the measured forces are the maximum values of continuously summed measurements. Scaled plots of selected signals and computed resultants were produced. Time integrals of sled acceleration signals were compared with velocity determined from displacement measurements.

FINDINGS

TEST BY TEST NARRATIVES

Test 1976 - A test of the Stencel lap belt. The maximum sled acceleration was 31.8 G, the maximum sled velocity was 93.0 ft/sec, and the duration of the acceleration pulse was 143 milliseconds. The measured belt slip through each adjuster was less than 1/2 inch. The manual release of the buckle functioned satisfactorily after the acceleration test.

Test 1977 - A test of the Stencel lap belt. The maximum sled acceleration was 38.3 G, The maximum sled velocity was 103 ft/sec, and the duration of the acceleration pulse was 131 milliseconds. The measured belt slip through each adjuster was less than 1/2 inch. The manual release of the buckle functioned satisfactorily after the acceleration test.

Test 1978 - A test of the Stencel lap belt. The maximum sled acceleration was 41.9 G, the maximum sled velocity was 106 ft/sec, and the duration of the acceleration pulse was 125 milliseconds. The lap belt material failed on the right side lap belt, preceding and precipitating total restraint harness failure.

Test 1979 - A test of the Frost lap belt. The maximum sled acceleration was 32.1 G, the maximum sled velocity was 93.1 ft/sec, and the duration of the acceleration pulse was 140 milliseconds. The measured belt slip through each adjuster was less than 1/2 inch. The manual release of the buckle functioned satisfactorily after the acceleration test.

Test 1980 - A test of the Frost lap belt. The maximum sled acceleration was 39.5 G, the maximum sled velocity was 103 ft/sec, and the duration of the acceleration pulse was 130 milliseconds. The measured belt slip through each adjuster was less than 1/2 inch. The manual release of the buckle functioned satisfactorily after the acceleration test.

Test 1981 - A test of the Frost lap belt. The maximum sled acceleration was 40.4 G, the maximum sled velocity was 104 ft/sec, and the duration of the acceleration pulse was 126 milliseconds. The measured belt slip through both lap belt adjusters was greater than 1/2 inch. The left side belt slipped approximately 9 inches and the right side slipped approximately 8 inches. The measured belt slip through the shoulder harness adjusters was less than 1/2 inch. The manual release of the buckle functioned satisfactorily after the test.

Test 1982 - A test of the Koch lap belt. The maximum sled acceleration was 33.2 G, the maximum sled velocity was 95.0 ft/sec, and the duration of the acceleration pulse was 143 milliseconds. The lap belt buckle failed, preceding and precipitating total restraint harness failure.

Test 1983 - A test of the Koch lap belt. The maximum sled acceleration was 41.2 G, the maximum sled velocity was 106 ft/sec, and the duration of the acceleration pulse was 125 milliseconds. The lap belt buckle failed, preceding and precipitating total restraint harness failure.

SUMMARY OF DATA

The test data collected from each test are summarized in Tables 2 to 9. These tables provide sled acceleration maximums, sled impact velocity, the maximum restraint strap loads in three axes, and the maximum magnitude of the resultant restraint strap load vectors.

Figures 9 to 11 contain graphs of the data collected from each of the above mentioned channels during test 1976. The data from all eight tests accomplished during this program are provided in Appendix B.

TABLE 2. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1976

<u>MAXIMUM SLED ACCELERATION</u> (G)	
X Axis	-31.78
Y Axis	2.91
Z Axis	2.77
<u>SLED VELOCITY AT IMPACT</u> (FT/SEC)	91.5
<u>SHOULDER HARNESS MAXIMUM LOAD</u> (LBS)	
X Axis	3494
Y Axis	221
Z Axis	937
Resultant	3618
<u>MAXIMUM LEFT LAP BELT LOAD</u> (LBS)	
X Axis	2692
Y Axis	1061
Z Axis	3787
<u>MAXIMUM RIGHT LAP BELT LOAD</u> (LBS)	
X Axis	2640
Y Axis	1227
Z Axis	2635
Resultant	3924

TABLE 3. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1977

MAXIMUM SLED ACCELERATION (G)	
X Axis	-38.25
Y Axis	3.53
Z Axis	3.42
SLED VELOCITY AT IMPACT (FT/SEC)	100.9
MAXIMUM SHOULDER HARNESS LOAD (LBS)	
X Axis	4093
Y Axis	180
Z Axis	1133
Resultant	4249
MAXIMUM LEFT LAP BELT LOAD (LBS)	
X Axis	3553
Y Axis	1278
Z Axis	2891
Resultant	4755
MAXIMUM RIGHT LAP BELT LOAD (LBS)	
X Axis	3465
Y Axis	1397
Z Axis	3197
Resultant	4918

TABLE 4. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1978

MAXIMUM SLED ACCELERATION (G)	
X Axis	-41.01
Y Axis	3.59
Z Axis	-5.94
SLED VELOCITY AT IMPACT (FT/SEC)	105.7
MAXIMUM SHOULDER HARNESS LOAD (LBS)	
X Axis	4092
Y Axis	720
Z Axis	1244
Resultant	4267
MAXIMUM LEFT LAP BELT LOAD (LBS)	
X Axis	3578
Y Axis	1339
Z Axis	2972
Resultant	4840
MAXIMUM RIGHT LAP BELT LOAD (LBS)	
X Axis	3327
Y Axis	1319
Z Axis	3077
Resultant	4720

TABLE 5. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1979

MAXIMUM SLED ACCELERATION (G)	
X Axis	-32.07
Y Axis	2.97
Z Axis	3.47
SLED VELOCITY AT IMPACT (FT/SEC)	91.8
MAXIMUM SHOULDER HARNESS LOAD (LBS)	
X Axis	3921
Y Axis	114
Z Axis	908
Resultant	4012
MAXIMUM LEFT LAP BELT LOAD (LBS)	
X Axis	2714
Y Axis	1053
Z Axis	2435
Resultant	3788
MAXIMUM RIGHT LAP BELT LOAD (LBS)	
X Axis	2744
Y Axis	1276
Z Axis	2659
Resultant	4029

TABLE 6. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1980

<u>MAXIMUM SLED ACCELERATION</u> (G)	
X Axis	-39.45
Y Axis	3.43
Z Axis	3.99
<u>SLED VELOCITY AT IMPACT</u> (FT/SEC)	101.5
<u>MAXIMUM SHOULDER HARNESS LOAD</u> (LBS)	
X Axis	4529
Y Axis	116
Z Axis	1074
Resultant	4643
<u>MAXIMUM LEFT LAP BELT LOAD</u> (LBS)	
X Axis	3326
Y Axis	1350
Z Axis	2863
Resultant	4591
<u>MAXIMUM RIGHT LAP BELT LOAD</u> (LBS)	
X Axis	3337
Y Axis	1433
Z Axis	3263
Resultant	4878

TABLE 7. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1981

MAXIMUM SLED ACCELERATION (G)	
X Axis	-40.41
Y Axis	3.57
Z Axis	3.56
SLED VELOCITY AT IMPACT (FT/SEC)	102.5
MAXIMUM SHOULDER HARNESS LOAD (LBS)	
X Axis	4403
Y Axis	272
Z Axis	1047
Resultant	4512
MAXIMUM LEFT LAP BELT LOAD (LBS)	
X Axis	2528
Y Axis	1049
Z Axis	2428
Resultant	3659
MAXIMUM RIGHT LAP BELT LOAD (LBS)	
X Axis	3030
Y Axis	1317
Z Axis	2922
Resultant	4379

TABLE 8. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1982

MAXIMUM SLED ACCELERATION (G)	
X Axis	-33.16
Y Axis	2.56
Z Axis	3.95
SLED VELOCITY AT IMPACT (FT/SEC)	93.4
MAXIMUM SHOULDER HARNESS LOAD (LBS)	
X Axis	1843
Y Axis	70
Z Axis	342
Resultant	1969
MAXIMUM LEFT LAP BELT LOAD (LBS)	
X Axis	2426
Y Axis	842
Z Axis	2118
Resultant	3318
MAXIMUM RIGHT LAP BELT LOAD (LBS)	
X Axis	2384
Y Axis	1060
Z Axis	2163
Resultant	3386

TABLE 9. SUMMARY OF THE ELECTRONICALLY MEASURED AND COMPUTED DATA FROM TEST 1983

MAXIMUM SLED ACCELERATION (G)	
X Axis	-41.01
Y Axis	3.58
Z Axis	4.42
SLED VELOCITY AT IMPACT (FT/SEC)	104.6
MAXIMUM SHOULDER HARNESS LOAD (LBS)	
X Axis	1987
Y Axis	42
Z Axis	360
Resultant	2013
MAXIMUM LEFT LAP BELT LOAD (LBS)	
X Axis	2062
Y Axis	884
Z Axis	1824
Resultant	2891
MAXIMUM RIGHT LAP BELT LOAD (LBS)	
X Axis	1666
Y Axis	529
Z Axis	1646
Resultant	2401

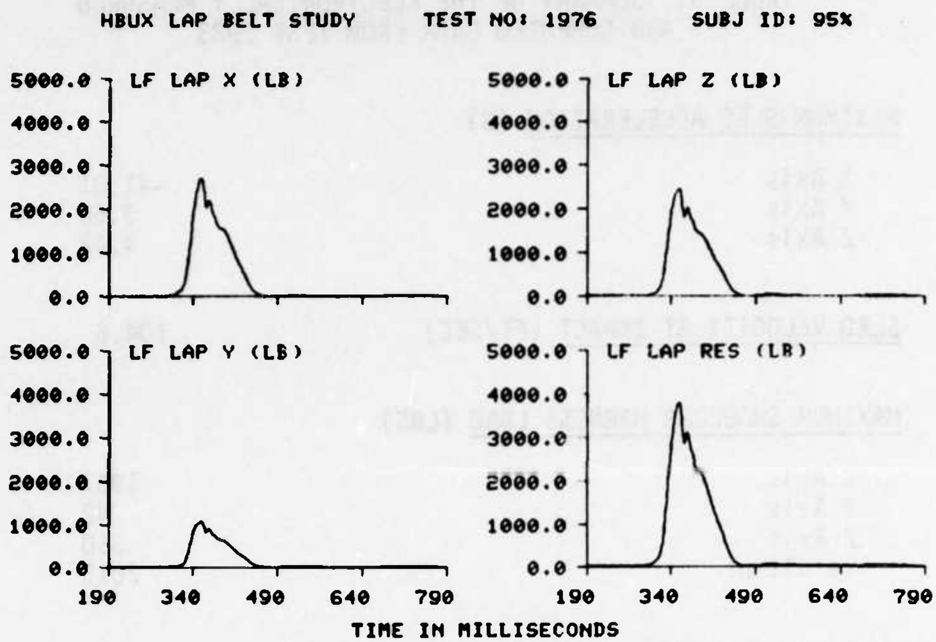


FIGURE 9. ELECTRONIC DATA GRAPHS FROM TEST 1976

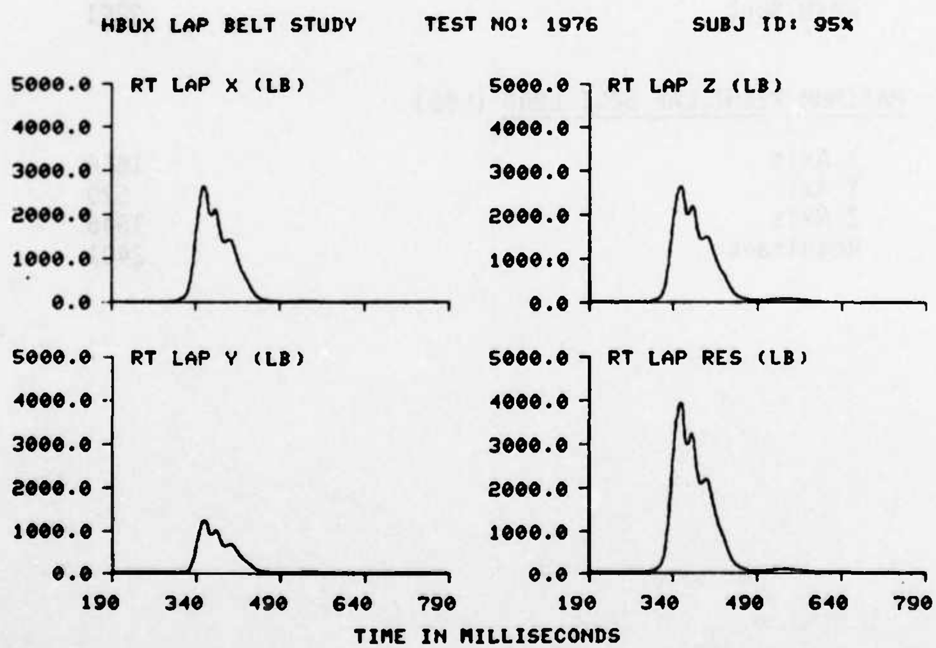


FIGURE 10. ELECTRONIC DATA GRAPHS FROM TEST 1976

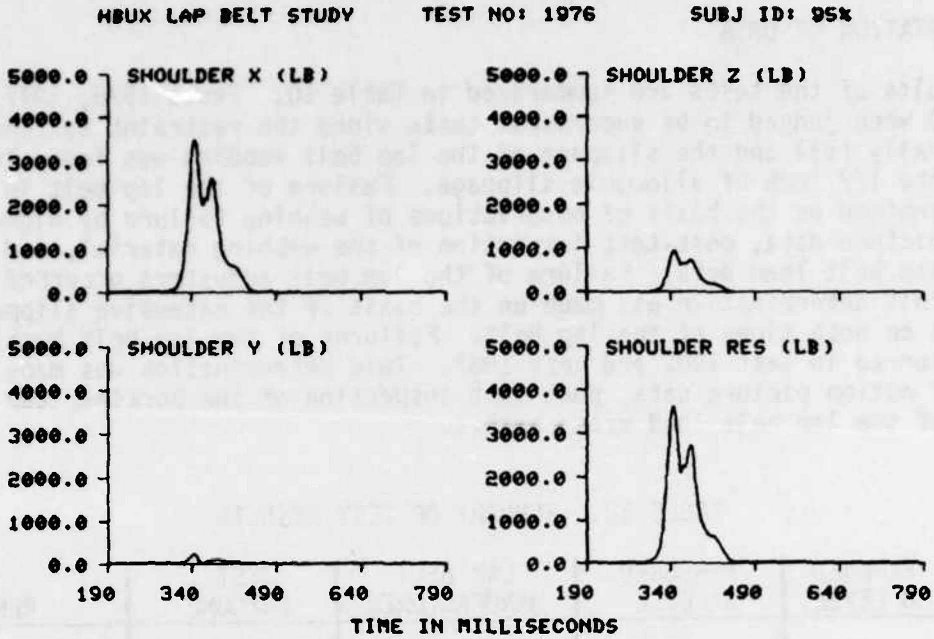


FIGURE 11. ELECTRONIC DATA GRAPHS FROM TEST 1976

DISCUSSION

INTERPRETATION OF DATA

The results of the tests are summarized in Table 10. Tests 1976, 1977, 1979, and 1980 were judged to be successful tests since the restraint systems did not structurally fail and the slippage of the lap belt webbing was found to be within the 1/2 inch of allowable slippage. Failure of the lap belt in test 1978 was determined on the basis of observations of webbing failure by high-speed motion picture data, post-test inspection of the webbing material, and analysis of the lap belt load data. Failure of the lap belt adjusters occurred in test 1981. This determination was made on the basis of the extensive slippage measured on both sides of the lap belt. Failures of the lap belt buckle mechanism occurred in test 1982 and test 1983. This determination was made on the basis of motion picture data, post-test inspection of the buckles, and interpretation of the lap belt load measurements.

TABLE 10. SUMMARY OF TEST RESULTS

TEST NO.	PLANNED G LEVEL	MEASURED G LEVEL	LAP BELT MANUFACTURER	TEST OUTCOME	REMARKS
1976	32	31.8	STENCEL	SUCCESS	
1977	38	38.3	STENCEL	SUCCESS	
1978	40	41.9	STENCEL	FAILURE	BELT FAILED
1979	32	32.1	FROST	SUCCESS	
1980	38	39.5	FROST	SUCCESS	
1981	40	40.4	FROST	FAILURE	BELT SLIPPAGE
1982	32	33.2	KOCH	FAILURE	BUCKLE FAILED
1983	38	41.0	KOCH	FAILURE	BUCKLE FAILED

The case of the webbing failure on test 1978 appeared to be a sharp radius on the lap belt buckle. The cause of the belt slipage of test 1981 may have been incompatibility between the adjuster design and the webbing material. This adjuster was originally qualified for application in the U.S. Army Blackhawk helicopter restraint system using a webbing material that is more flexible than the webbing used in these tests.

Higher than programmed X axis acceleration measured on tests 1978, 1982, and 1983 resulted after failure of the restraint systems, the higher acceleration occurred because the total mass of the sled being propelled by the Impulse Accelerator is reduced as the dummy is released.

The two failures of the Koch lap belt buckle appeared to have resulted from structural deficiencies.

Although the lap belt webbing and the buckle mechanism did not fail on test 1981, this test was judged to be an inadequate test of the webbing and buckle since the loads in the belt were reduced by the adjuster slippage. The maximum resultant load measured at the left lap belt attachment was 3658 lbs. and at the right lap belt attachment it was 4378 lbs. In contrast, the left and right lap belt resultant loads were 4591 lbs. and 4878 lbs., respectively, in test 1980 where the adjuster slippage was less than 1/2 inch. However, since the buckle and webbing did not fail in test 1980 at 39.5 G, there was no evidence to conclude that the buckle and webbing would have failed under the 40.4 G condition of test 1981 if the adjusters had not slipped.

Prototypes of each of the contractor's lap belt designs were subjected to static loading tests by each contractor prior to the accomplishment of the dynamic tests described in this report. Each prototype withstood the applied static load. This fact highlights the importance of dynamic testing.

RECOMMENDATIONS

Further tests of the two adjusters are recommended. Tests of the Koch and East/West adjusters should be performed with the Frost buckle to compare their efficacy under 40 G conditions.

In the future automotive crash dummies should be used in tests of this type. These dummies have been developed to simulate the dynamic mechanical responses of the human body to $-G_X$ impact. Although the simulation is not completely accurate, these dummies would provide more realistic loading of the restraint system and thereby provide more assurance of the structural adequacy of restraint systems under operational conditions.

SUMMARY AND CONCLUSIONS

Eight impact tests were performed to evaluate preproduction HBU-X lap belts supplied by three contractors. The impact tests were performed at 32, 38, and 40 G levels with impact velocities ranging up to 106 ft/sec.

The Stencel and Frost lap belts successfully completed impact tests at the 32 and 38 G levels.

The Stencel lap belt structurally failed at the 40 G level.

The Frost lap belt failed the 40 G level test due to excessive lap belt slippage through the adjusters.

The buckle of the Koch lap belt failed at the 32 and 38 G levels.

Further tests of each of the Koch and East/West adjusters are warranted.

Further tests of the Frost buckle are recommended since there was no evidence of failure of this unit in any of the tests. These tests should be performed with other lap belt adjusters or with other webbing material that might be less likely to slip through the adjusters supplied with the Frost lap belt.

APPENDIX A

DATA ACQUISITION EQUIPMENT AND METHODS

ACCELEROMETERS

The sled acceleration was measured using two Endevco Model 2264 accelerometers and one Endevco Model 2262 accelerometer. These accelerometers were rigidly fastened to the test sled to measure the accelerations in the X, Y, and Z axis. Figure A - 1 shows the coordinate system utilized for the testing and the corresponding output polarity for an applied acceleration. The package was oriented such that the Model 2262 transducer measured the primary acceleration and the Model 2264 accelerometers measured the secondary axes. The specifications for these accelerometers are shown in Figures A - 2 and A - 3.

HARNESS INSTRUMENTATION

The harness instrumentation consisted of four load measuring transducers located at the four points the harness attached to the seat. The harness and seat are shown in Figure A - 4. Two types of transducers were used in measuring harness loads. Three GM triaxial load cells were used to measure lap belt and shoulder harness loads. One Strainsert load cell, shown in Figure A - 5, was used to measure the negative G strap load. All load cell outputs were wired to correspond with the coordinate system shown in Figure A - 6. All of the transducers produced a positive output when placed under tension in accordance with the coordinate system shown in Figure A - 1. The Digital Instrumentation Requirments sheet of Figure A - 7 contains the pertinent data for all of the transducers used in the test program.

CALIBRATION

Strainsert load cells were calibrated on a periodic basis at the Precision Measurement Equipment Laboratories (PMEL), Wright-Patterson Air Force Base. The PMEL documents the calibration test results by a certificate which provides sensitivity and linearity data.

Accelerometers were calibrated using AFAMRL facilities. These calibrations were performed prior to and upon the completion of each phase of the test program. Calibration of each test accelerometer was performed to determine sensitivty, phase, and frequency characteristics by using a reciprocity method. This method utilizes a shaker table to physically vibrate the test and standard accelerometers simultaneously for comparison of their outputs. The laboratory standard accelerometer is calibrated yearly to standards traceable to the National Bureau of Standards. The frequency response and phase characteristic of each accelerometer was obtained using a random noise generator to drive the shaker assembly and analyzing the output data by Fourier analysis using a PDP 11/15 computer and a Time Data unit. Accelerometer natural frequency and dampening factor are also derived and computed from this information.

ACCELEROMETER COORDINATE SYSTEM

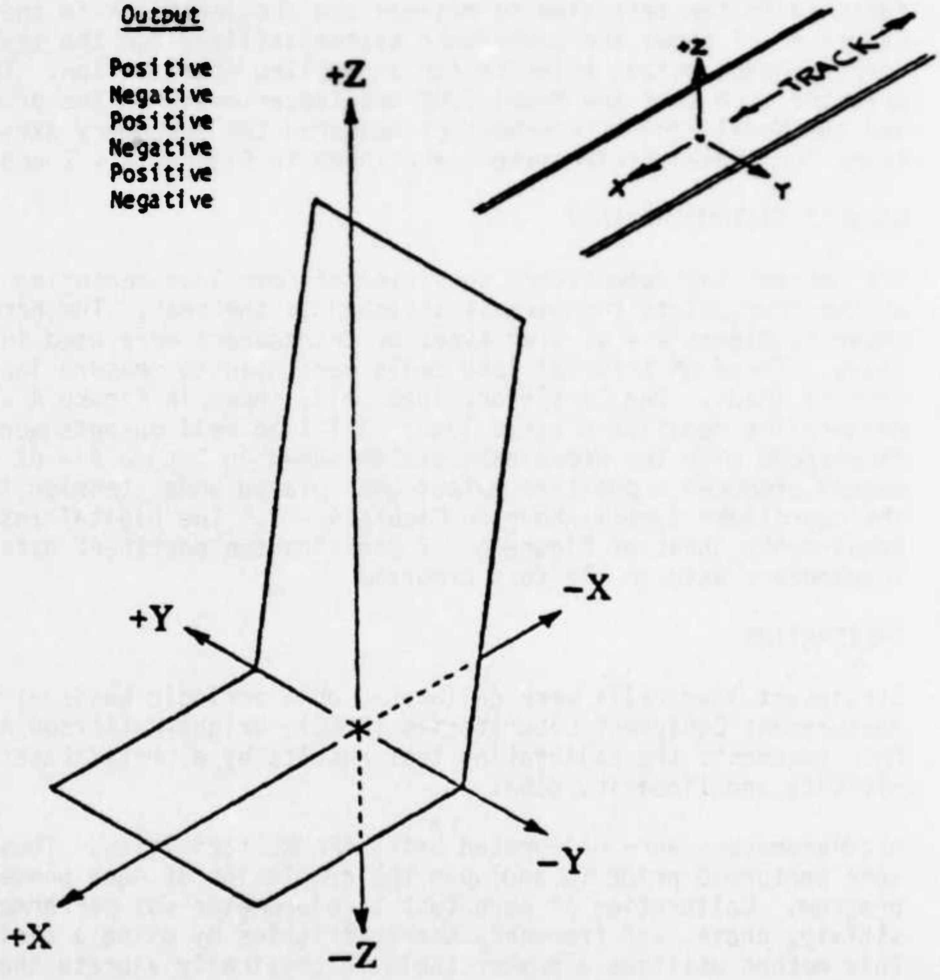
ACCELERATION

Accelerometers will be oriented and wired to provide an output corresponding to the applied acceleration. Use this table as a reference:

Acceleration	Output
+Gx	Positive
-Gx	Negative
+Gy	Positive
-Gy	Negative
+Gz	Positive
-Gz	Negative

BARE SLED AND MACHINE TESTS

Accelerometers will be oriented to provide outputs to agree with track coordinate system with polarities as noted in test log.



AMRL BBP COORDINATE SYSTEM

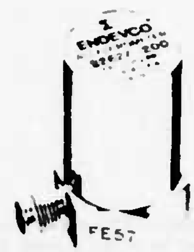
(Left Hand Rule)

FIGURE A-1

The Endevco Models 2262A-100, 2262CA-100, 2262A-200 and 2262CA-200 are rugged, fluid-damped accelerometers of the peizoresistive type. Piezite® Type P-11 semiconductor strain gage elements are used in a full bridge configuration providing a low impedance output of 500 mV full scale with 10 Vdc excitation. This output is high enough to drive most tape recorders and low frequency galvanometers directly, without amplification.

The Models 2262CA-100 and 2262CA-200 have two active arms and two precision fixed resistors of 1 000Ω each to provide for shunt calibration in a six-wire system. They are provided with a six conductor shielded cable assembly.

The frequency range of the Models 2262A-100 and 2262CA-100 extend from static to 2 000 Hz. The Models 2262A-200 and 2262CA-200 are available with a frequency range from static to 3 000 Hz. Positive overtravel stops prevent damage to the seismic system, giving an overrange capability of 2 000 g. The use of viscous damping extends their useful frequency range and reduces the effect of spurious, high-frequency vibrations.



SPECIFICATIONS FOR MODEL 2262A-100, 2262CA-100, 2262A-200 and 2262CA-200 ACCELEROMETERS
(According to ANSI and ISA Standards)

	Models 2262A-100 (2262CA-100)*	**Models 2262A-200** (2262CA-200)*
DYNAMIC		
RANGE	-100 g to 100 g	-200 g to 200 g
OVERRANGE LIMITING[1]	±150 to ±750 g	±300 to ±1 200 g
SENSITIVITY	5 mV/g typical (2.5 mV/g typical)	2.5 mV/g typical (1.2 mV/g typical)
	4 mV/g minimum (2 mV/g minimum)	2 mV/g minimum (1 mV/g minimum)
MOUNTED NATURAL FREQUENCY (AT 75°F)	5 000 Hz typical	7 000 Hz typical
FREQUENCY RESPONSE[2]	±5% maximum 0 to 2 000 Hz at 75°F; -35%/10% typical at 0/200°F and 2 000 Hz	±5% maximum 0 to 3 000 Hz at 75°F; -35%/10% typical at 0/200°F and 3 000 Hz
DAMPING RATIO	0.7 typical	0.7 typical
TRANSVERSE SENSITIVITY[3]	3% maximum	3% maximum
THERMAL SENSITIVITY SHIFT	-5/0/5% typical at 0/75°F/200°F	
LINEARITY AND HYSTERESIS	+2% of reading, maximum, to 100 g	+2% of reading, maximum, to 200 g
ELECTRICAL		
EXCITATION[4]	10.00 Vdc	10.00 Vdc
INPUT RESISTANCE (AT 75°F)	1 800 Ω typical (1 000 Ω typical)	1 800 Ω typical (1 000 Ω typical)
OUTPUT RESISTANCE (AT 75°F)	1 200 Ω typical (1 000 Ω typical)	1 200 Ω typical (1 000 Ω typical)
INSULATION RESISTANCE[5]	100 GΩ minimum	100 GΩ minimum
ZERO MEASURAND OUTPUT	±25 mV maximum	±25 mV maximum
THERMAL ZERO SHIFT	±20 mV maximum at 0°F and 200°F reference 75°F (24°C)	

NOTES

*Specifications in perantheses are for 2262CA, shunt calibration versions

[1]Unit is not rated for use above the specified range, but output is continuous in the region between full range and the effective limit point.

[2]Response is ±5%, 0 Hz to 500 Hz for Model 2262A-100, and 0 Hz to 750 Hz for Model 2262A-200, over the temperature range of 0°F to 200°F.

[3]Worst case error in any direction, perpendicular to sensitive axis

[4]Unit is calibrated at 10.0 Vdc. Lower excitation voltges may be employed, but should be specified at time of order to obtain best thermal compensation. Warmup time to meet all specifications is 2 minutes. Endevco Model 4470 Signal Conditioner is recommended as the excitation source

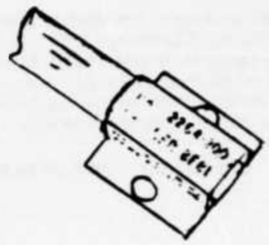
[5]Measured with 100 Vdc, maximum, all leads to case. Cable shield common to case.

FIGURE A-2

MODEL 2264-200

±200 g
One gram

MINIATURE PIEZORESISTIVE ACCELEROMETER



The Model 2264-200 is a very low mass, piezoresistive accelerometer designed for model studies, flutter testing and similar applications requiring good low frequency response and minimum mass loading.

With only a small amount of damping, the Model 2264-200 has no phase shift over its useful frequency range of steady state to 1200 Hz. Protection against overranging results from the high environmental rating of ±1000 g peak. The accelerometer can be operated over a temperature range of 0°F to 150°F (−18°C to 66°C).

The 2264-200 utilizes Piezite® Element Type P-11 gages in a half bridge circuit providing a low impedance nominal output of 500 mV full scale at 10 Volts dc excitation.

SPECIFICATIONS FOR MODEL 2264-200 ACCELEROMETER

DYNAMIC	
RANGE	−200 g to +200 g
SENSITIVITY (at rated excitation)	2.5 mV/g, nominal; 2.0 mV/g, minimum
MOUNTED RESONANCE FREQUENCY	4700 Hz, nominal
AMPLIFICATION FACTOR, Q	10, maximum, at resonance and 75°F
FREQUENCY RESPONSE (reference 100 Hz)	±10% max., 0 to 1200 Hz at +75°F (24°C)
TRANSVERSE SENSITIVITY	3%, maximum
LINEARITY AND HYSTERESIS	±2% of reading, maximum, 0 to 150 g; ±2.5% of reading, maximum, 0 to 200 g.
THERMAL SENSITIVITY SHIFT	±40 mV max., at 0°F and 150°F (−18°C and 66°C), ref. 75°F (24°C)
WARMUP TIME	1 minute
ELECTRICAL	
EXCITATION	10.0 V dc
RESISTANCE PER ARM	1700Ω ± 20%, at +75°F (24°C)
ZERO MEASURAND OUTPUT	±50 mV dc max., at +75°F
THERMAL ZERO SHIFT	±40 mV max., at 0°F and 150°F (−18°C and 66°C)
INSULATION RESISTANCE	10MΩ minimum at 100 V dc

ENVIRONMENTAL

ACCELERATION LIMIT (in any direction)	Static:	±1000 g.
	Sinusoidal:	±1000 g pk.
	Shock:	±1000 g pk, 1.5 millisecond duration or longer. CAUTION: Keep protective sleeve on accelerometer until ready to use.
TEMPERATURE	Operating:	0°F to 150°F (−18°C to 66°C)
	Non-Operating:	−65°F to 200°F (−54°C to 93°C)
HUMIDITY		Epoxy Sealed
ALTITUDE		Not Affected

FIGURE A-3

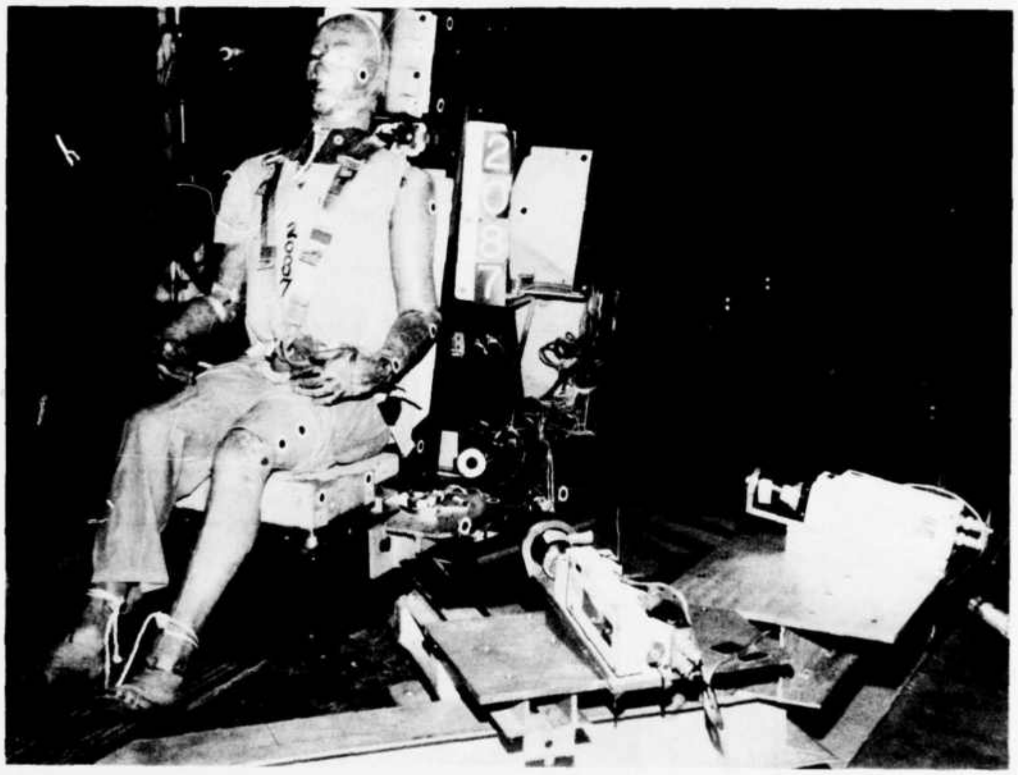


FIGURE A-4

FLAT LOAD CELL SPECIFICATIONS

	GENERAL PURPOSE	PRECISION
BRIDGE	350Ω±3½Ω; SINGLE or DUAL BRIDGE	
EXCITATION	20V AC or DC MAX. 15V AC or DC RECOMMENDED	
OUTPUT SIGNAL	2 mV/V or 3 mV/V	
NON-REPEATABILITY	±0.05% FS	
NON-LINEARITY	±0.25% FS	±0.10% FS
SPAN CALIBRATION	±0.25% FS	±0.10% FS
HYSTERESIS	±0.15% FS	±0.10% FS
TEMPERATURE EFFECT ON ZERO ON OUTPUT (15°F to 115°F)	0.0025% FS/°F 0.0025% of LOAD/°F	0.0015% FS/°F 0.0015% of LOAD/°F
SAFE STATIC OVERLOAD WITHOUT ZERO or CALIBRATION CHANGE WITHOUT STRUCTURAL FAILURE	200% FS for 2 mV/V 150% FS for 3 mV/V 250% FS for 2 mV/V 200% FS for 3 mV/V	
ZERO BALANCE	±1% FS	

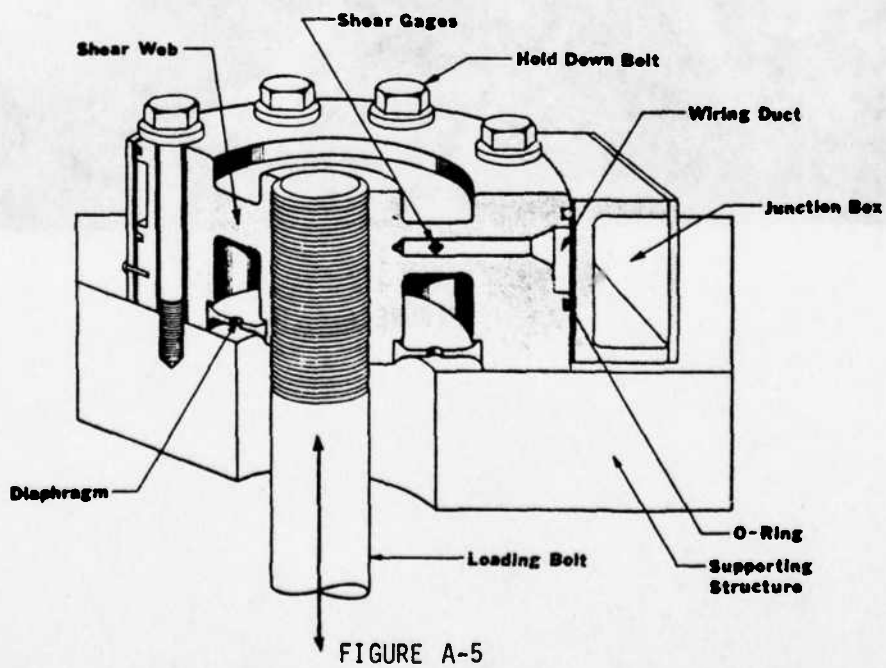
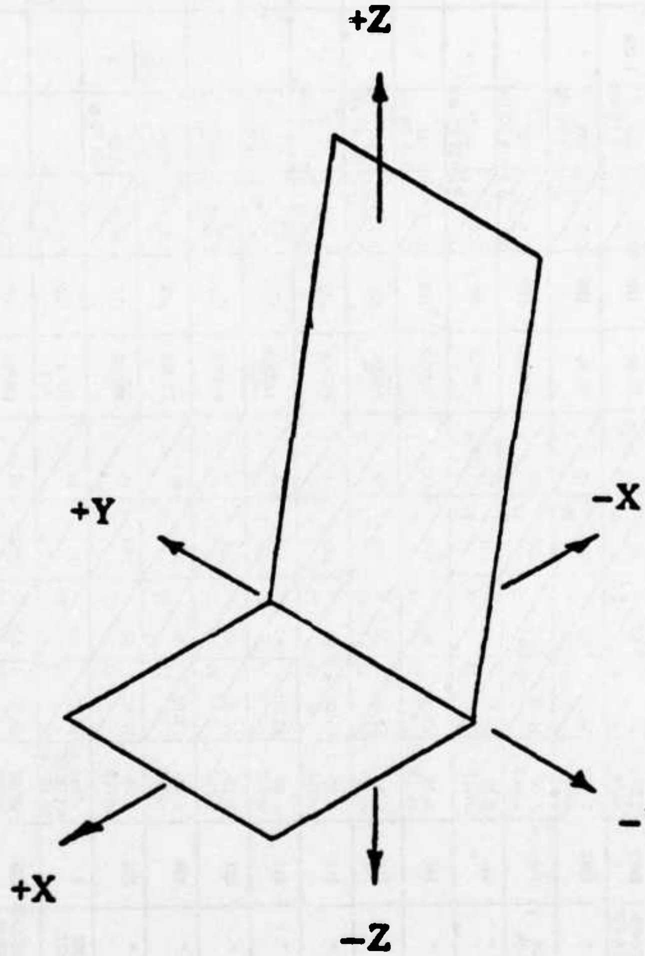


FIGURE A-5

LOAD CELL COORDINATE SYSTEM

load cells will be wired to provide a positive output when the belt is pulled.



AMRL BBP COORDINATE SYSTEM

(Left Hand Rule)

FIGURE A-6

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM: HBUX LAP BELTS DATE: 5 JAN 82 THRU: * 17 FEB 82

FACILITY: HORIZONTAL IMPULSE ACCELERATOR RUN: 2020 THRU: * 2088

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
1	SLED X	ENDEVCO 2262A-200	FR42	4.138 mv/g	10.00	1	60	1	10	2	1K	1	60.4g	120	2.5	+5.0 -0.0	375K -IN TO GND	-	
2	SLED Y	ENDEVCO 2264-200	BW92	2.385 mv/g	10.00	2	60	2	50	5	1K	1	21.0g	120	2.5	+5.0 -0.0	100K -IN TO GND	1.63K	
3	SLED Z	"	BX48	2.653 mv/g	10.00	3	60	3	50	26	1K	1	18.8g	120	2.5	+5.0 -0.0	254K -IN TO GND	"	
15	LEFT LAP LOAD X	GM 30-SM	15X	5.04 uv/LB	10.00	15	60	15	100	19	1K	1	4960LB	120	2.5	+5.0 -0.0	50K +IN TO GND	-	
16	LEFT LAP LOAD Y	"	15Y	5.30 uv/LB	10.00	16	60	16	201	1	1K	1	2347LB	120	2.5	+5.0 -0.0	13.7K +IN TO GND	-	
17	LEFT LAP LOAD Z	"	15Z	6.24 uv/LB	10.00	17	60	17	100	5	1K	1	4006LB	120	2.5	+5.0 -0.0	15K +IN TO GND	-	
18	RIGHT LAP LOAD X	"	21X	4.95 uv/LB	10.00	18	60	18	100	16	1K	1	5051LB	120	2.5	+5.0 -0.0	13.5K +IN TO GND	-	
19	RIGHT LAP LOAD Y	"	21Y	4.90 uv/LB	10.00	19	60	19	201	8	1K	1	2538LB	120	2.5	+5.0 -0.0	17.3K +IN TO GND	-	
20	RIGHT LAP LOAD Z	"	21Z	6.06 uv/LB	10.00	20	60	20	100	31	1K	1	4125LB	120	2.5	+5.0 -0.0	90K -IN TO GND	-	
21	SHOULDER LOAD Z	"	20X	5.11 uv/LB	10.00	21	60	21	201	9	1K	1	2434LB	120	2.5	+5.0 -0.0	160K +IN TO GND	-	USE LOAD CELL X AXIS CAL.
22	SHOULDER LOAD Y	"	20Y	5.46 uv/LB	10.00	22	60	22	402	13	1K	1	1139LB	120	2.5	+5.0 -0.0	800K +IN TO GND	-	
23	SHOULDER LOAD X	"	20Z	6.29 uv/LB	10.00	23	60	23	100	2	1K	1	3975LB	120	.40	+5.0 -0.0	52K -IN TO GND	-	
29	VELOCITY	GLOBE 22A672	2	.2664 VOLTS FPS 10.25" WHEEL	10.00	29	60	29	1	-	1K	1	117.2 FPS	120	2.5	+5.0 -0.0	-	-	6.242 ATTENUATOR LOCATED IN SIG. COND. SENS. ÷ .2664 VOLTS FPS = .04253 V/FPS ATTEN. 6.242 POSITIVE OUTPUT
30	N-G STRAP	STRAINSERT FL1U-2SG	207	19.81 uv/LB	10.00	30	60	30	100	21	1K	1	1262LB	120	2.5	+5.0 -0.0	-	-	USED FOLLOWING TESTS: 2022,2024,2029

COMPUTER START: -6 SEC.
STOP: +4 SEC.

* NOTE: THE FOLLOWING TESTS CONDUCTED DURING PERIODS INDICATED 2020 THRU 2033, 5 JAN 82 THRU 15 JAN 82 2080 THRU 2088, 9 FEB 82 THRU 17 FEB 82

PAGE 1 OF 2

FIGURE A-7A

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM: NBUX LAP BELTS DATE: 5 JAN 82 THRU: 15 JAN 82

FACILITY: HORIZONTAL IMPULSE ACCELERATOR RUN: 2020 THRU: 2033

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	E/N	AMP GAIN	S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
37	EVENT	-	-	-	-	37	1000	30	2.5	9	1K	1	2.5 VOLT	2000	2.5	+5.0 -0.0	-	-	EVENT IS NEG. PULSE
47	2.5V BIAS	-	-	-	-	47	180	14	1	-	1K	1	2.5 VOLT	360	2.5	+5.0 -0.0	-	-	
48	10V.EXC.	-	-	-	10.00	48	180	27	1	-	1K	1	5.0 VOLT	360	5.0	+5.0 -0.0	-	-	

PAGE 2 OF 2

FIGURE A-7B

Harness load cells were calibrated under tension load on a special test fixture. The sensitivity and linearity of each device was obtained by comparing its output to that of a standard load cell mounted to the test fixture. The standard load cell is calibrated on a yearly basis by standards traceable to the National Bureau of Standards.

All calibration records are maintained on file for reference. The pre and post test calibration data for the devices calibrated by AFAMRL are shown in the Table of Figure A - 8.

AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM

SLED-BORNE DATA ACQUISITION SYSTEM

The Sled-Borne Data Acquisition (SBDA) System is shown in Figure A - 9. A block diagram of SBDA system is shown in Figure A - 10. This system consists of four parts: the power conditioner, the signal conditioner, the encoder and the junction box. The power conditioner receives a 28 vdc, 4A power source and provides several regulated supplies. They are the +15 and -12 vdc (0.8A) supply for the signal conditioners, the 5 vdc and the 10 vdc bridge excitation voltages (1.2A total), and the 2.5 vdc signal output bias voltage (0.1A). The original 28 vdc source also powers the pulse code modulator (PCM) encoder. The signal conditioner consists of 48 signal modules. Each module is capable of processing a sensor (transducer) signal which can be a voltage generating source or a bridge-type sensor. If a bridge-type sensor is used, the bridge excitation voltage is selectable from the 5 V or the 10 V source. The bridge (half or full bridge) can be completed and balanced by connecting external resistors to the module input connector.

The signal conditioning module has two sections. The amplifier section has seven programmable gains to cover the input signal dynamic ranges from 50 MV to 5 V. The filter section has four programmable frequencies according to the SAE recommended classes, 60, 180, 600, and 1000. There are three external connectors for each signal module. The input connector connects a signal source or a bridge, the balance resistors, the bridge completion resistors, the excitation voltage, and the reference offset. The gain plug selects one of the seven amplifier gains and the filter frequency plug selects one of the four filter classes.

The 48 channel data signals are time multiplexed via an encoder which digitizes the 48 analog data sources into 48 11-bit digital words. Two additional 11-bit synchronization (sync) words are added to the data frame. The 50-word frame is then sampled at a rate of 1000 samples/second. This serial digital data along with three additional synchronization pulse trains (bit sync, word sync, and frame sync) are connected to the computer room by four twisted pairs incorporated into a drag cable. They pass through a junction box to the digital computer interface to allow recording and processing.

PDP 11-34 DATA COLLECTION AND STORAGE

A PDP 11-34 minicomputer is the main control for all electronic data collection and storage functions. The block diagram of Figure A - 11 shows the processor

PROGRAM HBUX LAP BELTS

DATE 3 Nov 81

FACILITY RUN NO'S 1974-1983

HORIZONTAL IMPULSE ACCELERATOR

DATA POINT	TRANSDUCER MFG & MODEL	S/N	PRE CAL		POST CAL		% CHANGE	COMMENTS
			DATE	SENS uv/LB	DATE	SENS uv/LB		
Left Lap Load X	GM3D-SW	15X	23 Sep 81	5.00	18 Nov 81	5.04	+ .8	
Left Lap Load Y	"	15Y	"	5.33	"	5.30	+ .6	
Left Lap Load Z	"	15Z	"	6.23	"	6.24	+ .2	
Right Lap Load X	"	21X	"	4.89	"	4.95	+1.2	
Right Lap Load Y	"	21Y	"	4.83	"	4.90	+1.4	
Right Lap Load Z	"	21Z	"	6.04	"	6.06	+ .3	
Shoulder Load X	"	20X	"	5.07	"	5.11	+ .8	
Shoulder Load Y	"	20Y	"	5.43	"	5.46	+ .6	
Shoulder Load Z	"	20Z	"	6.35	"	6.29	- .9	

FIGURE A-8

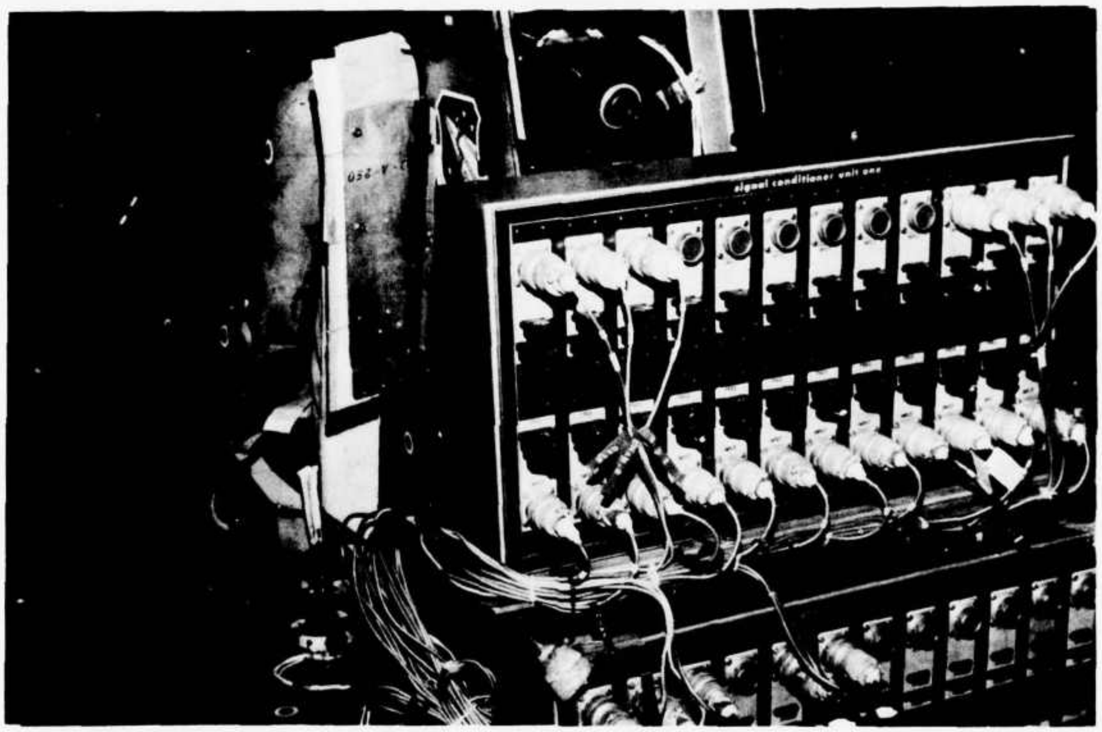


FIGURE A-9

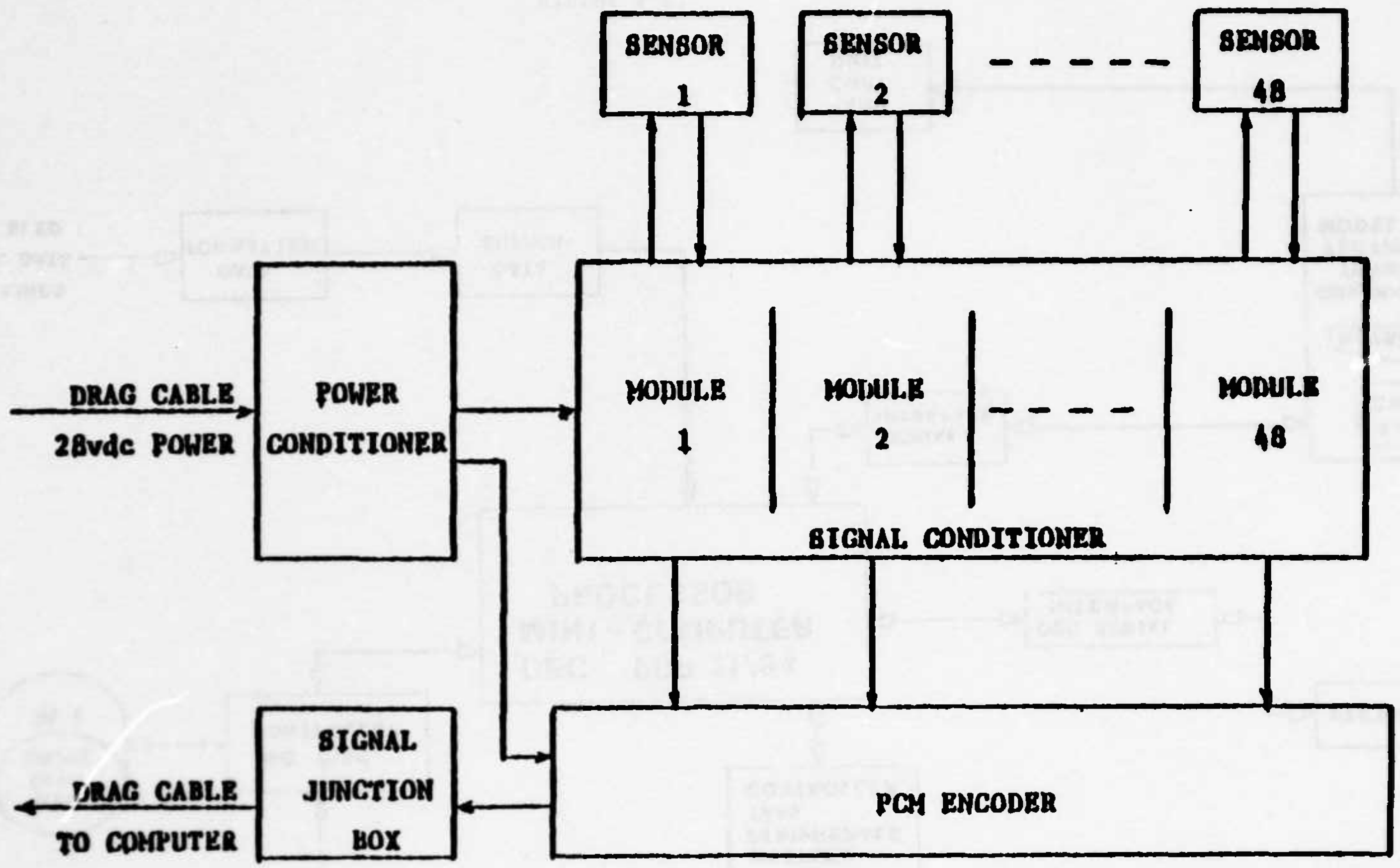

SENSOR 1
SENSOR 2
SENSOR 48
DRAG CABLE
28vdc POWER
POWER CONDITIONER
MODULE 1
MODULE 2
MODULE 48
SIGNAL CONDITIONER
SIGNAL JUNCTION BOX
DRAG CABLE
TO COMPUTER
PCM ENCODER

FIGURE A-10

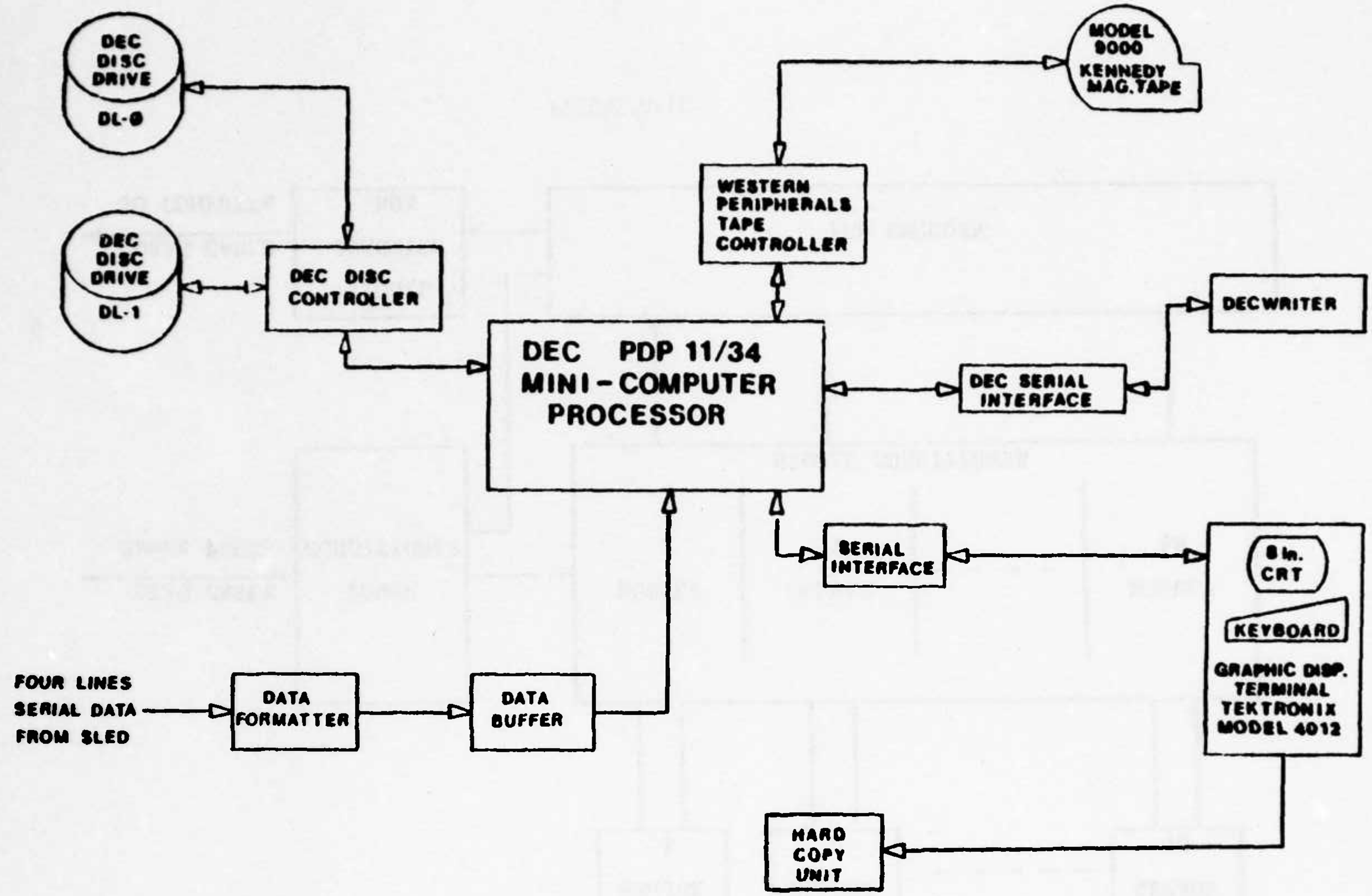

DEC DISC DRIVE DL-0
DEC DISC DRIVE DL-1
DEC DISC CONTROLLER
WESTERN PERIPHERALS TAPE CONTROLLER
MODEL 9000 KENNEDY MAG.TAPE
DEC PDP 11/34 MINI-COMPUTER PROCESSOR
DEC SERIAL INTERFACE
DECWRITER
SERIAL INTERFACE
8 In. CRT
KEYBOARD
GRAPHIC DISP. TERMINAL TEKTRONIX MODEL 4012
FOUR LINES SERIAL DATA FROM SLED
DATA FORMATTER
DATA BUFFER
HARD COPY UNIT

FIGURE A-11

and its related equipment. All data transfer in the data collection system is under software control by the central processor unit. Serial data are constantly being received by the data formatter unit from the sled data encoder. These data are converted by the data formatter from serial to parallel for input via a buffered data channel to computer memory for storage on disk. Finally, the data is transferred from disk to magnetic tape for permanent storage following the test event.

QUICK LOOK INERTIAL DATA

After each test, the data were sampled and checked. This check was made using the Single Channel Analysis (SCAN) routine for the PDP 11-34 processor. This routine allows the operator to access and plot up to 2000 points of data for any of the 48 channels. The SCAN program can process vertical or horizontal deceleration data under operator control. The operator selects the channel to be processed and enters its location description as well as the start and stop points to be processed. A maximum of 2000 milliseconds or 2000 data points may be accessed for each plot. The program converts the raw data into the appropriate units of measure and calculates the minimum and maximum values during the sample interval. If the sample is acceleration data, the velocity will also be calculated using an integration process. An added optional feature is a digital smoothing routine which can smooth the data to remove any excess high frequency component that may be present.

TIMING REFERENCE - INERTIAL DATA

A 100 Hz timing reference was an integral part of the Data Acquisition System. Figure A - 12 shows the timing signal wave shape. This 100 Hz signal was initiated at T-0 by the count down clock. 30 milliseconds after T-0, a second signal marking was generated and provided a temporal reference for electronic and photometric data.

KINEMATIC DATA ACQUISITION SYSTEM

Kinematic data were acquired through the use of high-speed 16mm cameras operating at a rate of 500 frames per second. The cameras were Photosonic model No. 16MM-1B pin registered units which were capable of withstanding 100 G. Two cameras were mounted on the test sled and one camera was mounted off the sled. During a test the cameras were started and stopped automatically by the Camera and Lighting Control Station which is part of the impact faciliy safety and control system. The cameras were started at a preset time in the test sequence and run for a period of 4 seconds per test.

AUTOMATIC FILM READER

An Automatic Film Reader (AFR) subsystem, developed by Photo Digitizing Systems, Inc., was used to automatically digitize and record photographic data on magnetic tape. The subsystem consists of:

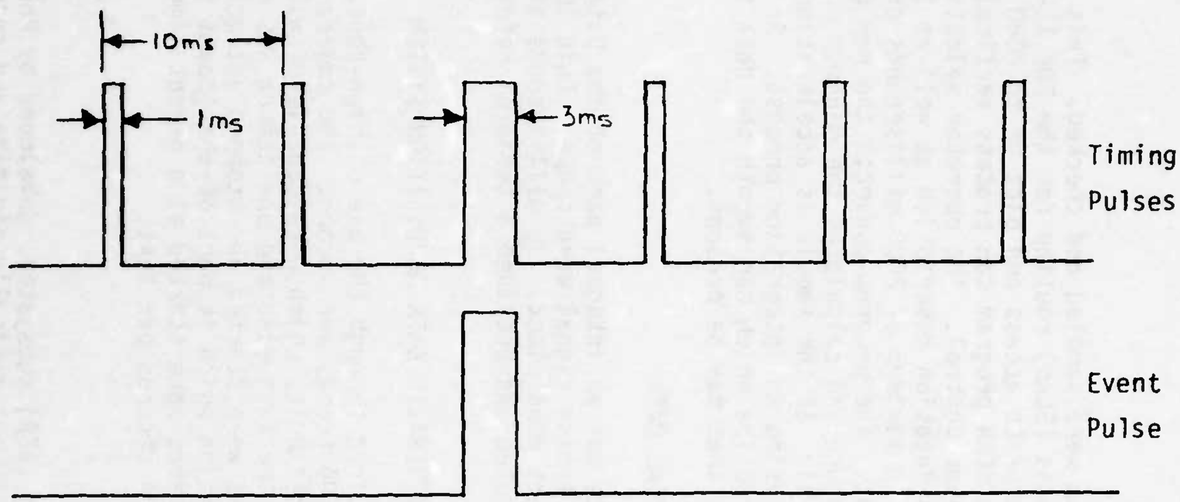


FIGURE A-12

Film motion analyzer with 16mm projection head
Electronic scanning camera
Control unit
Alphanumeric Cathode Ray Tube (CRT)
Line printer
Magnetic tape transport

The film reader recognizes quadrant or circular fiducial targets. It automatically tracks and extracts data for up to ten targets per film frame at a minimum rate of one-half film frame per second. Film may be processed through the reader manually or automatically. Figure A - 13 is a block diagram of the Automatic Film Reader System (AFR). The X-Y coordinate position of each target on each film frame is input to the computer and recorded on magnetic tape.

A NOVA 3/12 computer, which contains 16K 16-bit words of core memory, a CRT terminal, and a magnetic tape transport with suitable interface, controls the AFR. In addition, a parallel data link is provided between the NOVA 3/12 and the PDP 11/34 computers.

An alphanumeric CRT (DGC 6052) automatically displays the AFR control information. The CRT display and its keyboard function are used as separate devices. The keyboard is a transmit-only device and the display is a receive-only device but has the additional capability of transmitting cursor position information on program request.

A line printer, LA36 Decwriter II, provides hard copies of the information presented on the 6052 CRT. The LA36 is a medium-sized interaction terminal with a low-speed impact printer and a standard ASCII keyboard consisting of alphanumeric characters and non-printing system control codes.

Either the Decwriter or the 6052 CRT output may be assigned to the PDP 11/34A. Programs can also be established which can "down load" from the disc on the PDP 11/34A to the NOVA, or digital film data can be loaded on the PDP 11/34A for processing or disc storage.

QUICK LOOK KINEMATIC DATA

An Instar (Instant Analytical Replay) video camera, recording and monitor system was used to record each impact event. This video tape was available for review by the test conductor immediately after the impact event.

The Instar is a compact, portable, fully transistorized instrument that combines the long recording capacity and instant replay features of video tape. Each system records 120 frames/second with an effective shutter speed of 10us or less and will play back all recordings in real time, stop action, reverse slow motion, and variable slow motion (2%-15% of real time). Each of the frames is sequential and non-interlaced.

The Instar system that was used incorporates two cameras and a special effects generator for the added flexibility of split screen. The simultaneous display

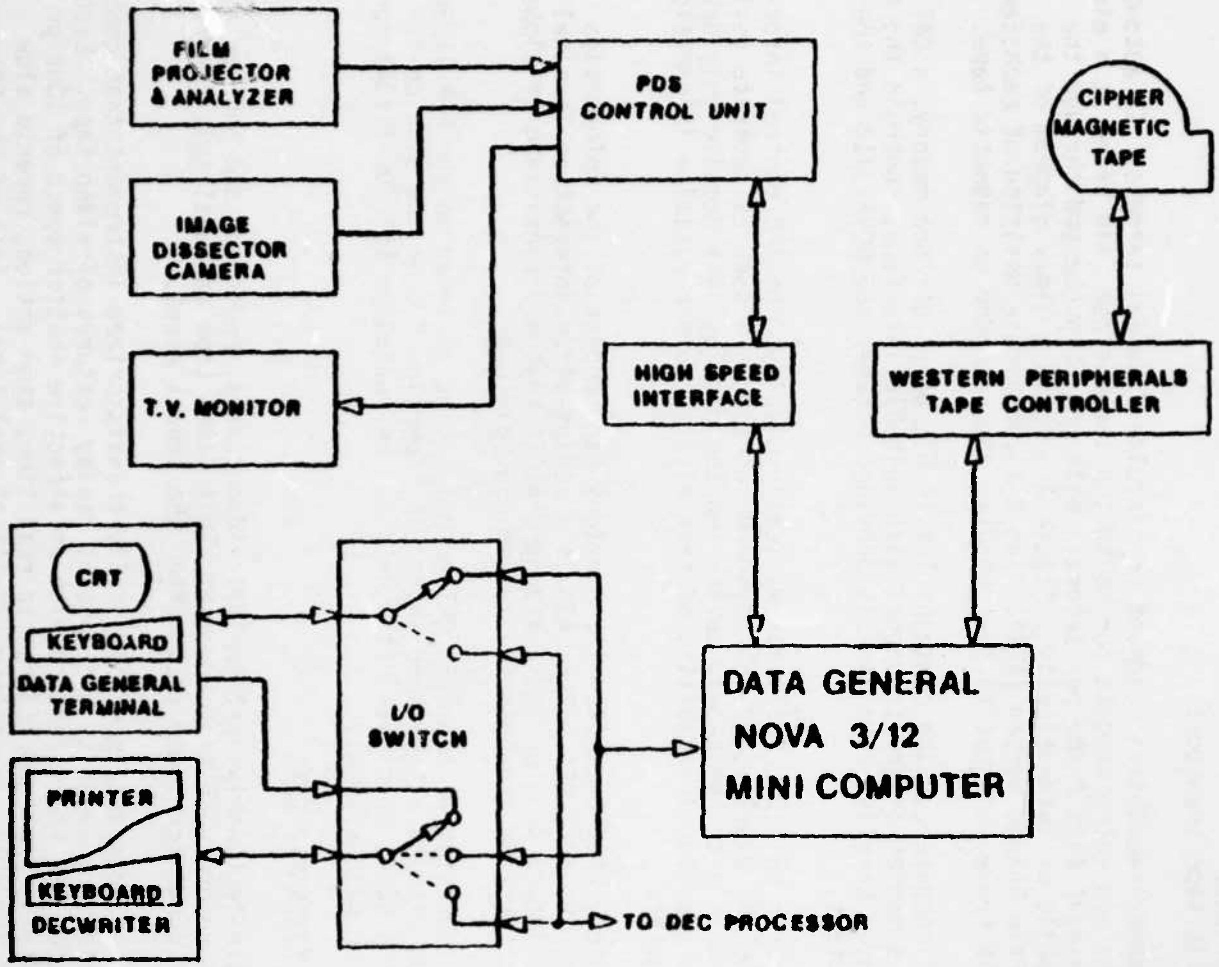
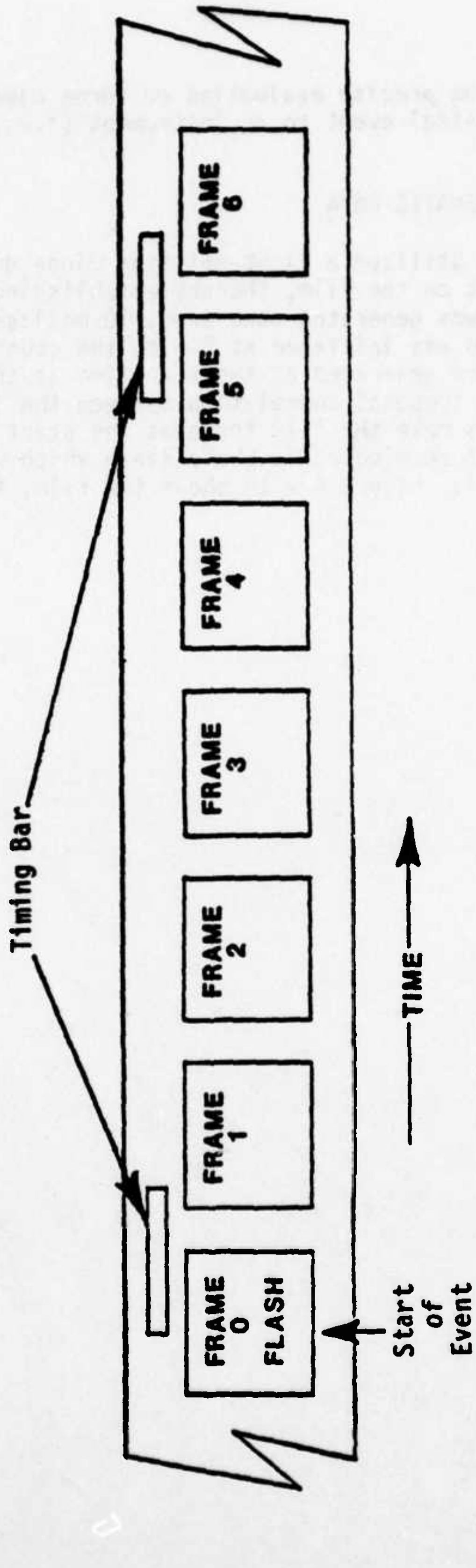

FILM PROJECTOR & ANALYZER
IMAGE DISSECTOR CAMERA
T.V. MONITOR
PDS CONTROL UNIT
CIPHER MAGNETIC TAPE
HIGH SPEED INTERFACE
WESTERN PERIPHERALS TAPE CONTROLLER
CRT
KEYBOARD
DATA GENERAL TERMINAL
PRINTER
KEYBOARD
DECWRITER
I/O SWITCH
DATA GENERAL
NOVA 3/12
MINI COMPUTER
TO DEC PROCESSOR

FIGURE A-13

of two events offers the precise evaluation of three dimensional problems or the referencing of one physical event to an instrument (i.e., digital clock or oscilloscope).

TIMING REFERENCE - KINEMATIC DATA

The high-speed cameras utilized a light-emitting diode driver, LM Dearing Model 2/3/3R, to place a mark on the film, thereby establishing a time reference. This mark (a red bar) was generated once every 10 milliseconds for a duration of 0.75 millisecond and was initiated at T-0 by the count down clock. These photo timing pulses were generated at the same time as the electronic timing pulses, thus providing temporal correlation between the two signals. A special event flash was used to make the film frame at the start of the impact event. This flash consisted of an electronic photo flash which was actuated by the electronic event signal. Figure A - 14 shows the film, flash, and timing bars.



Timing Bar
FRAME 0 FLASH
FRAME 1
FRAME 2
FRAME 3
FRAME 4
FRAME 5
FRAME 6
TIME
Start of Event

FIGURE A-14

APPENDIX B

DATA SUMMARIES AND GRAPHS

This appendix contains the data collected from each test accomplished in this test series. These data are summarized in a table of maximum and minimum values with corresponding times of maximum and minimum values and in graphs of sled accelerations, sled velocity, and loads measured at the restraint tiedown points.

The data printed out in tabular form are identified by an abbreviated title. The data are listed in four columns titled max (the maximum value), min (the minimum value), T1 (the time the maximum value occurred), and T2 (the time the minimum value occurred). A fifth column identifies the data channel number. The values of time are specified in milliseconds. An event mark is used to synchronize the electronic and photometric data. The event time is the first data value specified on each table. To correlate a time value from one test to another the reader must calculate the values of T1 and T2 with respect to the common time event mark. For example, if the event mark time is 160 milliseconds and the max value of the resultant shoulder harness load occurs at 300 milliseconds, subtraction of the event mark time from the time of the max resultant shoulder harness load yields the correlated time value, 140 milliseconds.

The data titles are defined as follows:

TIME OF EVENT = Time of event correlation mark
2.5V EXT PWR = Monitor of 2.5 volt power
10V EXT PWR = Monitor of 10 volt power

SHD PLD PRIOR EVENT = Shoulder harness preload prior to impact
LF LAP PLD PRIOR EVENT = Left lap belt preload prior to impact
RT LAP PLD PRIOR EVENT = Right lap belt preload prior to impact

SLED X ACCEL = Sled acceleration in the X axis
SLED X ACCEL (5M) = Sled X acceleration smoothed using a - point moving average method
SLED Y ACCEL = Sled acceleration in the Y axis
SLED Z ACCEL = Sled acceleration in the Z axis

SLED VEL (INT ACCEL) = Sled velocity computed by integration of sled acceleration

SHOULDER LOAD X = The X axis component of the load acting at the shoulder harness tie down point

SHOULDER LOAD Y = The Y axis component of the load acting at the shoulder harness tie down point

SHOULDER LOAD Z = The Z axis component of the load acting at the shoulder harness tie down point

SHOULDER RESULTANT = The resultant of the continuously summed shoulder harness load components

SHOULDER RES/WT = The maximum resultant shoulder harness load divided by the total weight of the subject

LF LAP LOAD X = The X axis component of the load acting at the left lap belt tie down point

LF LAP LOAD Y = The Y axis component of the load acting at the left lap belt tie down point

LF LAP LOAD Z = The Z axis component of the load acting at the left lap belt tie down point

LF LAP RESULTANT = The resultant of the continuously summed left lap belt load components

RT LAP LOAD X = The X axis component of the load acting at the right lap belt tie down point

RT LAP LOAD Y = The Y axis component of the load acting at the right lap belt tie down point

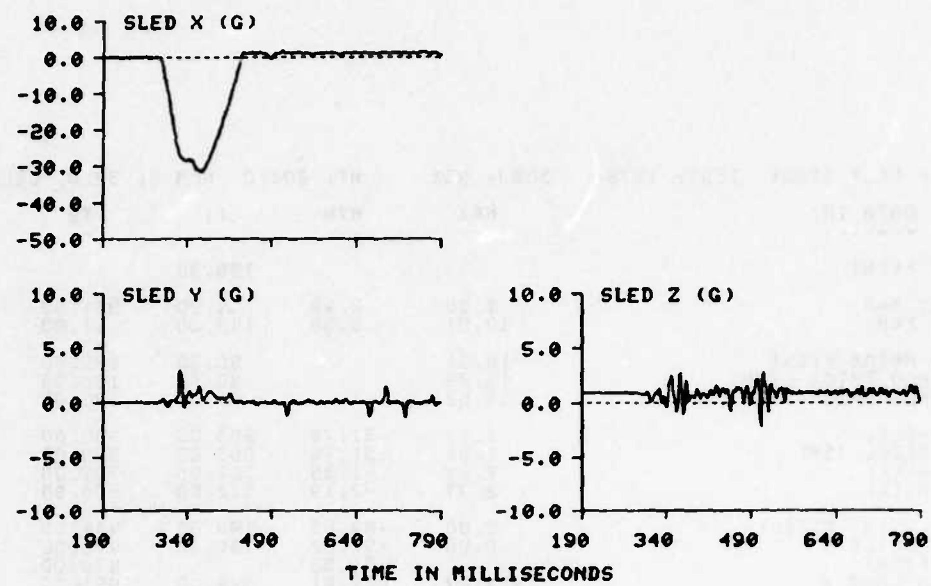
RT LAP LOAD Z = The Z axis component of the load acting at the right lap belt tie down point

RT LAP RESULTANT = The resultant of the continuously summed right lap belt load components

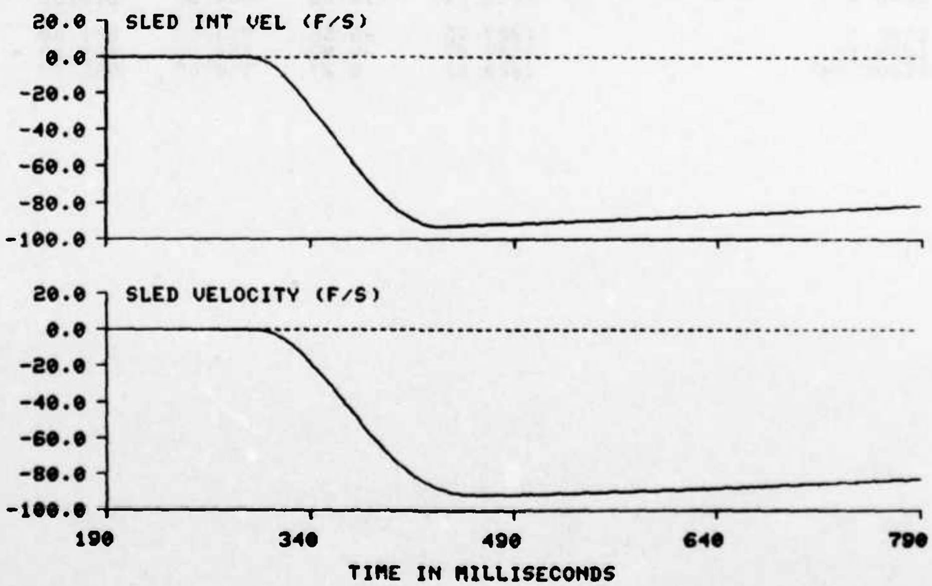
HBUX LAP BELT STUDY   TEST: 1976   SUBJ: 95%   WT: 204.0   NOM G: 32.0   CELL: X

DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			199.00		37
2.5V EXT PWR	2.50	2.49	4.00	361.00	47
10V EXT PWR	10.01	9.98	143.00	51.00	48
SHD PLD PRIOR EVENT	16.31		90.00	190.00	
LF LAP PLD PRIOR EVENT	16.99		90.00	190.00	
RT LAP PLD PRIOR EVENT	19.52		90.00	190.00	
SLED X ACCEL	1.68	-31.78	508.00	365.00	1
SLED X ACCEL (SM)	1.39	-31.44	509.00	365.00	
SLED Y ACCEL	2.91	-1.36	327.00	727.00	2
SLED Z ACCEL	2.77	-2.19	512.00	508.00	3
SLED VEL (INT ACCEL)	0.00	-93.06	190.00	436.00	
SLED VELOCITY	0.00	-91.52	190.00	470.00	29
VEL AT EVENT		-91.52		470.00	
SHOULDER LOAD X	3494.27	-24.01	344.00	491.00	23
SHOULDER LOAD Y	220.81	-7.01	343.00	494.00	22
SHOULDER LOAD Z	936.80	-7.31	346.00	507.00	21
SHOULDER RESULTANT	3617.99	0.42	344.00	555.00	
SHOULDER RES / WT	17.73	0.00			
LF LAP LOAD X	2692.22	-11.70	353.00	596.00	15
LF LAP LOAD Y	1061.20	-9.47	354.00	579.00	16
LF LAP LOAD Z	2443.40	-11.47	354.00	629.00	17
LF LAP RESULTANT	3787.40	1.80	354.00	586.00	
RT LAP LOAD X	2639.64	-12.68	354.00	612.00	18
RT LAP LOAD Y	1227.43	-5.56	354.00	261.00	19
RT LAP LOAD Z	2634.87	-4.80	355.00	645.00	20
RT LAP RESULTANT	3923.65	4.27	354.00	635.00	

HBUX LAP BELT STUDY TEST NO: 1976 SUBJ ID: 95%

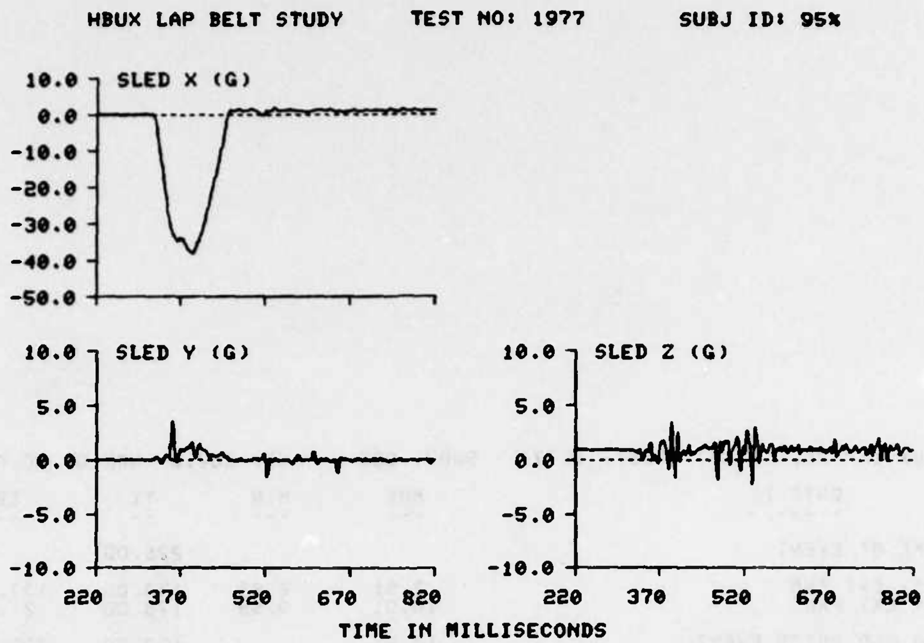


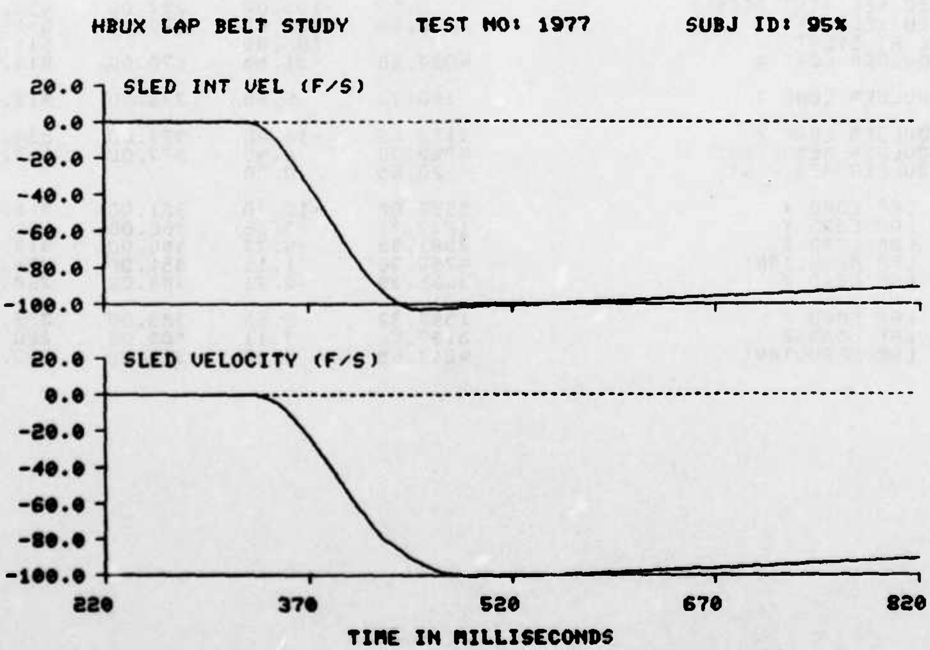
HBUX LAP BELT STUDY TEST NO: 1976 SUBJ ID: 95%

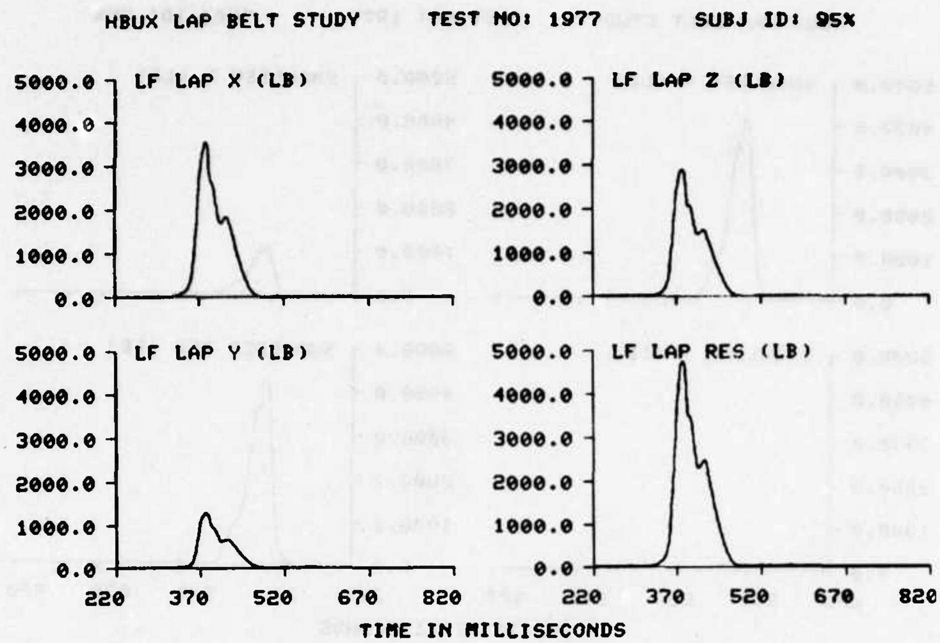


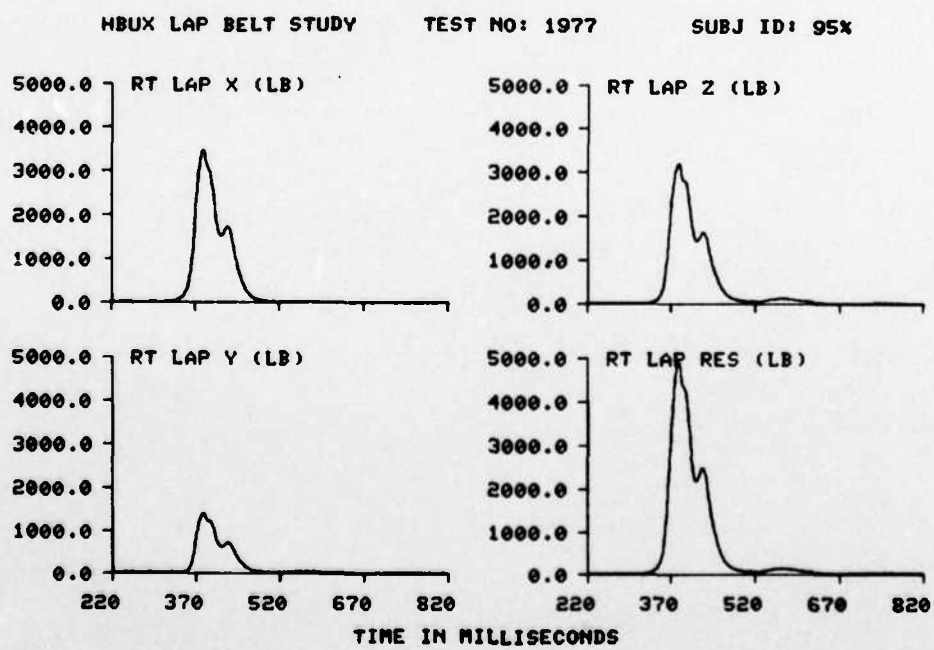
HBUX LAP BELT STUDY TEST: 1977 SUBJ: 95% WT: 204.0 NOM G: 40.0 CELL: X

DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			228.00		37
2.5V EXT PWR	2.51	2.48	143.00	137.00	47
10V EXT PWR	10.01	9.99	178.00	21.00	48
SHD PLD PRIOR EVENT	12.53		120.00	220.00	
LF LAP PLD PRIOR EVENT	14.31		120.00	220.00	
RT LAP PLD PRIOR EVENT	15.87		120.00	220.00	
SLED X ACCEL	1.97	-38.25	535.00	391.00	1
SLED X ACCEL (SM)	1.58	-37.82	535.00	390.00	
SLED Y ACCEL	3.53	-1.59	355.00	524.00	2
SLED Z ACCEL	3.42	-2.25	391.00	534.00	3
SLED VEL (INT ACCEL)	0.00	-103.02	237.00	453.00	
SLED VELOCITY	0.00	-100.89	220.00	511.00	29
VEL AT EVENT		-100.89		511.00	
SHOULDER LOAD X	4092.46	-31.88	370.00	514.00	23
SHOULDER LOAD Y	180.72	-5.88	373.00	519.00	22
SHOULDER LOAD Z	1132.59	-12.60	377.00	534.00	21
SHOULDER RESULTANT	4249.30	0.55	377.00	560.00	
SHOULDER RES / WT	20.83	0.00			
LF LAP LOAD X	3552.88	-10.70	381.00	516.00	15
LF LAP LOAD Y	1277.71	-7.56	380.00	664.00	16
LF LAP LOAD Z	2891.98	-4.73	380.00	614.00	17
LF LAP RESULTANT	4754.96	1.15	381.00	723.00	
RT LAP LOAD X	3465.38	-9.71	383.00	258.00	18
RT LAP LOAD Y	1397.32	-5.56	383.00	222.00	19
RT LAP LOAD Z	3197.06	7.11	383.00	220.00	20
RT LAP RESULTANT	4917.58	9.08	383.00	220.00	

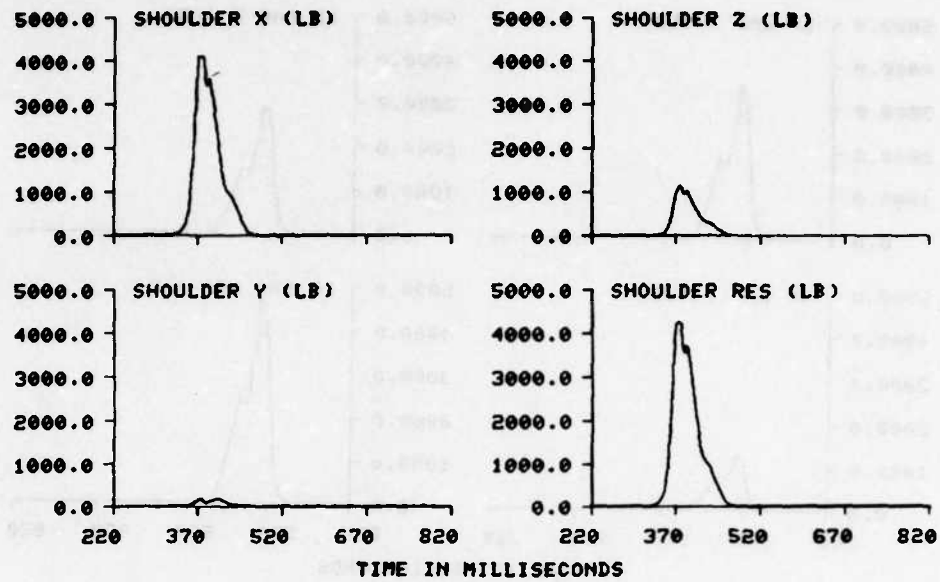

HBUX LAP BELT STUDY
TEST NO: 1977
SUBJ ID: 95%
SLED X (G)
SLED Y (G)
SLED Z (G)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
5.0
-5.0
220
370
520
670
820
TIME IN MILLISECONDS


HBUX LAP BELT STUDY
TEST NO: 1977
SUBJ ID: 95%
SLED INT VEL (F/S)
SLED VELOCITY (F/S)
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
220
370
520
670
820
TIME IN MILLISECONDS


HBUX LAP BELT STUDY
TEST NO: 1977
SUBJ ID: 95%
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
220
370
520
670
820
TIME IN MILLISECONDS


HBUX LAP BELT STUDY
TEST NO: 1977
SUBJ ID: 95%
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
220
370
520
670
820
TIME IN MILLISECONDS

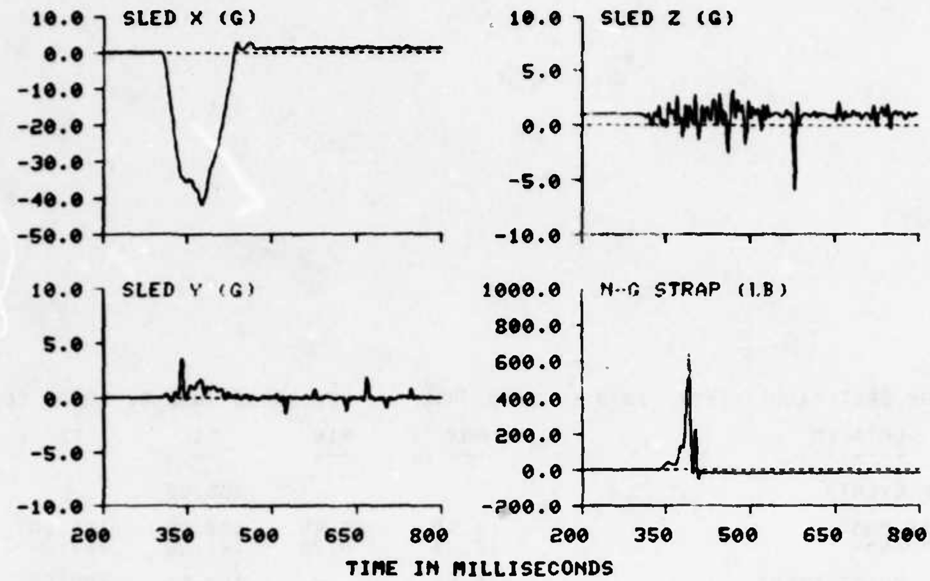
HBUX LAP BELT STUDY   TEST NO: 1977   SUBJ ID: 95%



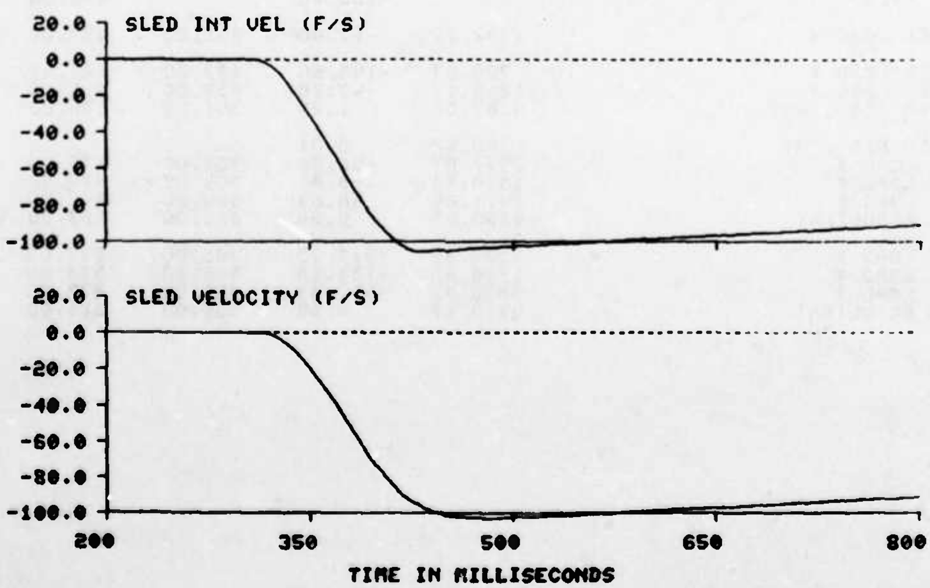
HBUX LAP BELT STUDY TEST: 1978 SUBJ: 95% WT: 204.0 NOM G: 40.0 CELL: X

DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			205.00		37
2.5V EXT PWR	2.51	2.49	302.00	141.00	47
10V EXT PWR	10.03	9.99	141.00	227.00	48
SHO PLD PRIOR EVENT	16.93		100.00	200.00	
LF LAP PLD PRIOR EVENT	14.29		100.00	200.00	
RT LAP PLD PRIOR EVENT	18.88		100.00	200.00	
SLED X ACCEL	2.75	-41.88	437.00	375.00	1
SLED X ACCEL (SM)	2.45	-41.01	460.00	375.00	
SLED Y ACCEL	3.59	-1.47	339.00	524.00	2
SLED Z ACCEL	3.20	-5.94	469.00	579.00	3
N-G STRAP	634.17	-54.60	390.00	407.00	30
SLED VEL (INT ACCEL)	0.01	-105.73	230.00	433.00	
SLED VELOCITY	0.00	-103.40	200.00	484.00	29
VEL AT EVENT		-103.40		484.00	
SHOULDER LOAD X	4092.22	-63.60	353.00	467.00	23
SHOULDER LOAD Y	720.67	-143.68	432.00	382.00	22
SHOULDER LOAD Z	1244.17	-43.26	432.00	468.00	21
SHOULDER RESULTANT	4267.06	1.23	361.00	510.00	
SHOULDER RES / WT	20.92	0.01			
LF LAP LOAD X	3577.87	-90.66	364.00	470.00	15
LF LAP LOAD Y	1338.64	-9.81	364.00	470.00	16
LF LAP LOAD Z	2971.84	-56.64	364.00	440.00	17
LF LAP RESULTANT	4839.93	0.89	364.00	523.00	
RT LAP LOAD X	3326.89	-311.73	365.00	373.00	18
RT LAP LOAD Y	1318.60	-133.18	365.00	373.00	19
RT LAP LOAD Z	3076.92	-311.63	365.00	372.00	20
RT LAP RESULTANT	4719.57	6.98	365.00	511.00	

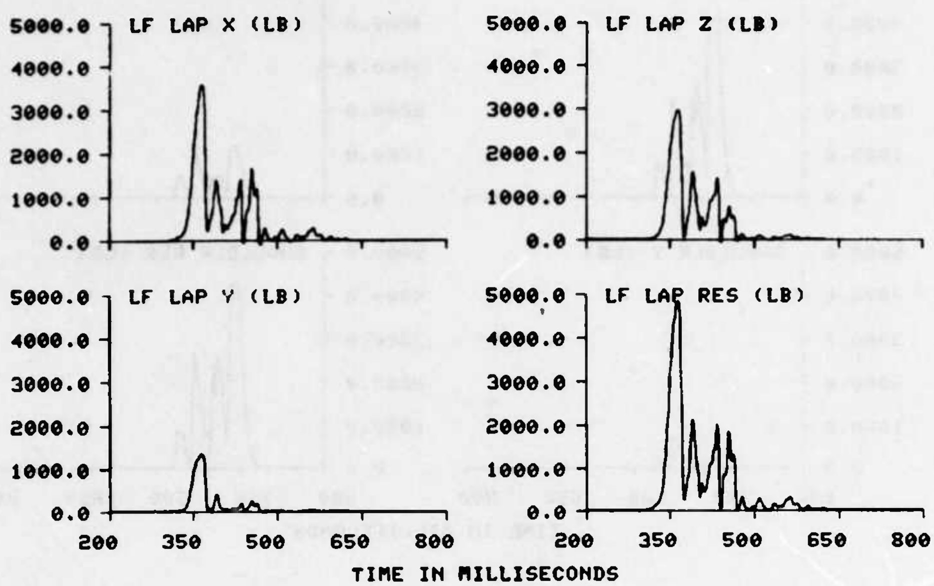
HBUX LAP BELT STUDY TEST NO: 1978 SUBJ ID: 95%



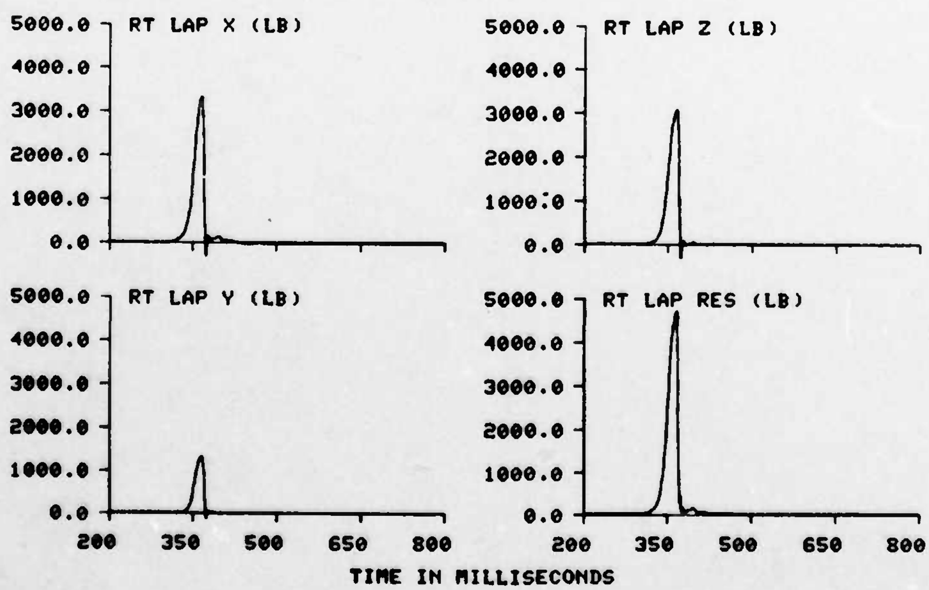
HBUX LAP BELT STUDY TEST NO: 1978 SUBJ ID: 95%

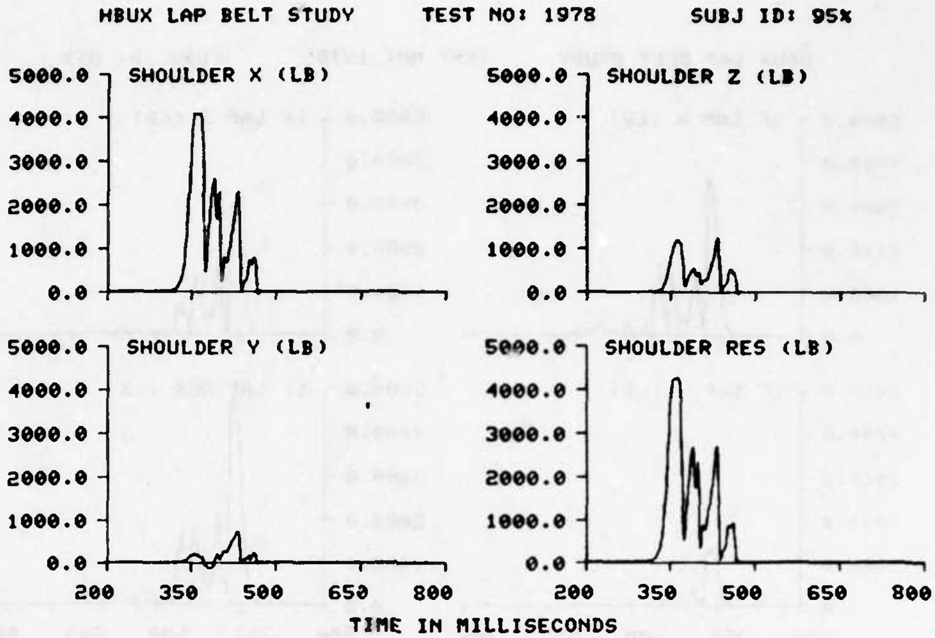


HBUX LAP BELT STUDY TEST NO: 1978 SUBJ ID: 95%



HBUX LAP BELT STUDY TEST NO: 1978 SUBJ ID: 95%



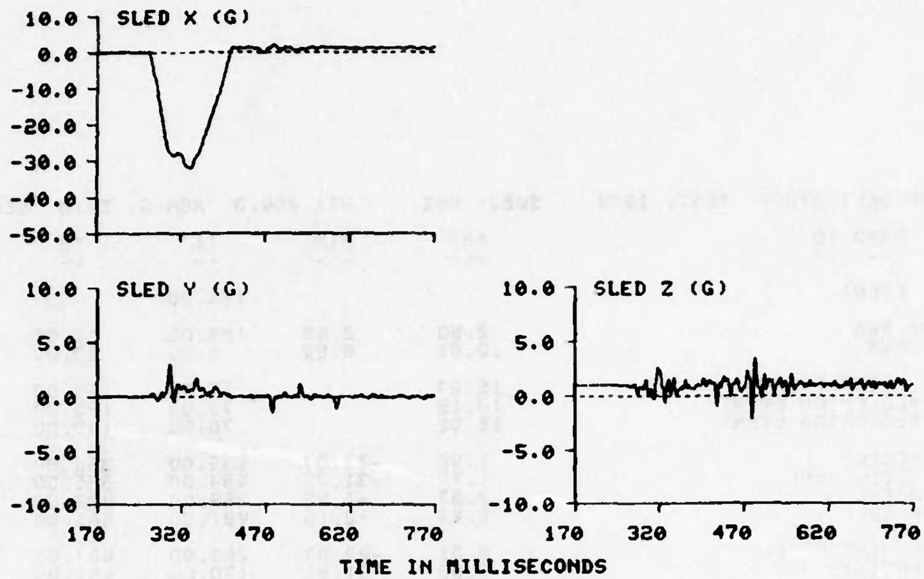


HBUX LAP BELT STUDY
TEST NO: 1978
SUBJ ID: 95%
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
200
350
500
650
800
TIME IN MILLISECONDS

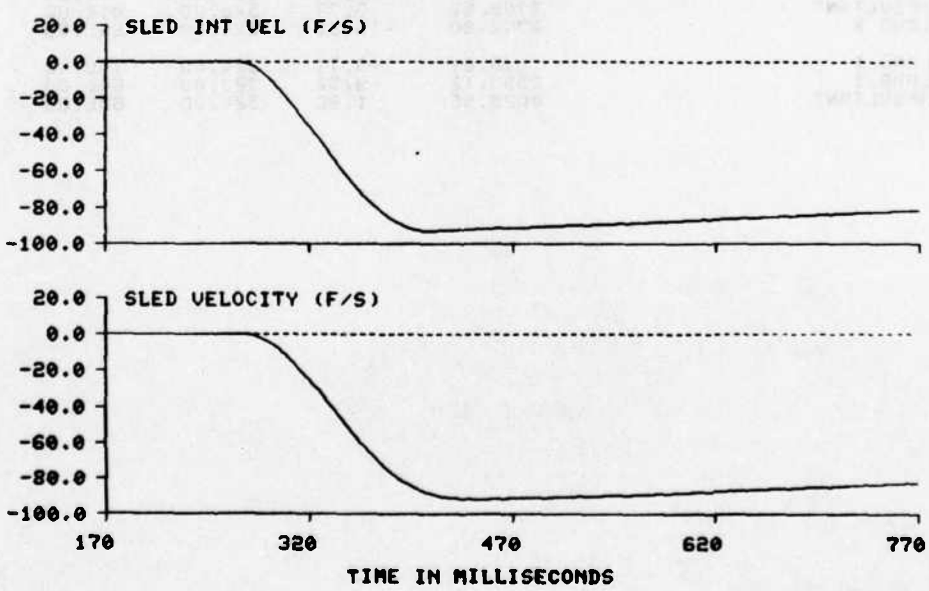
HBUX LAP BELT STUDY TEST: 1979 SUBJ: 95% WT: 204.0 NOM G: 32.0 CELL: X

DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			174.00		37
2.5V EXT PWR	2.50	2.49	169.00	67.00	47
10V EXT PWR	10.01	9.99	4.00	90.00	48
SHD PLD PRIOR EVENT	15.27		70.00	170.00	
LF LAP PLD PRIOR EVENT	19.16		70.00	170.00	
RT LAP PLD PRIOR EVENT	18.02		70.00	170.00	
SLED X ACCEL	1.99	-32.07	485.00	336.00	1
SLED X ACCEL (5M)	1.72	-31.75	484.00	335.00	
SLED Y ACCEL	2.97	-1.45	299.00	482.00	2
SLED Z ACCEL	3.47	-2.15	491.00	486.00	3
SLED VEL (INT ACCEL)	0.01	-93.07	253.00	407.00	
SLED VELOCITY	0.00	-91.81	170.00	451.00	29
VEL AT EVENT		-91.81		451.00	
SHOULDER LOAD X	3921.42	-33.89	315.00	469.00	23
SHOULDER LOAD Y	114.41	-55.02	316.00	346.00	22
SHOULDER LOAD Z	907.57	-9.56	319.00	485.00	21
SHOULDER RESULTANT	4011.75	1.75	315.00	437.00	
SHOULDER RES / WT	19.67	0.01			
LF LAP LOAD X	2713.72	-10.20	322.00	491.00	15
LF LAP LOAD Y	1052.76	-6.25	323.00	218.00	16
LF LAP LOAD Z	2434.82	-12.03	321.00	613.00	17
LF LAP RESULTANT	3788.42	0.77	322.00	614.00	
RT LAP LOAD X	2744.30	-15.33	324.00	695.00	18
RT LAP LOAD Y	1275.81	-3.71	324.00	760.00	19
RT LAP LOAD Z	2659.12	-9.52	323.00	848.00	20
RT LAP RESULTANT	4028.56	1.90	324.00	606.00	

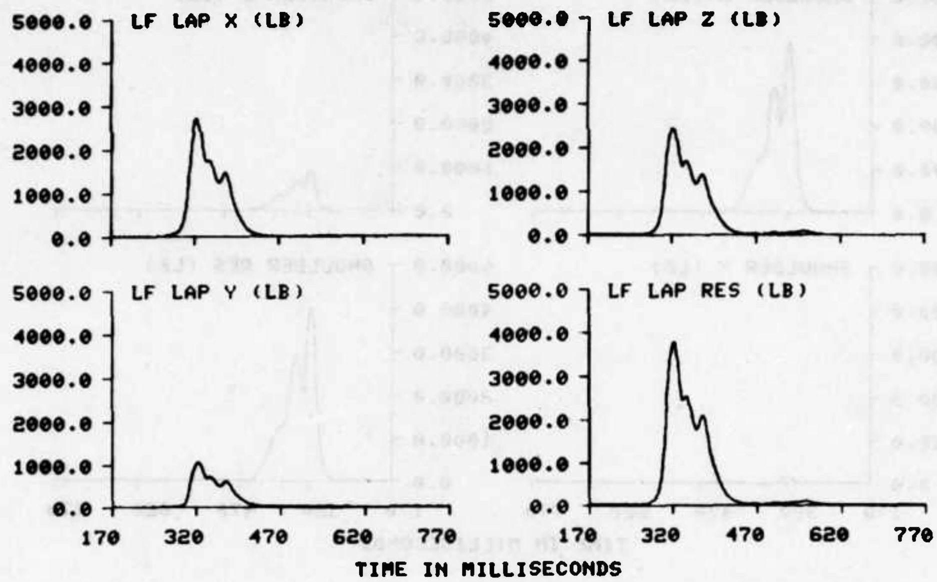
HBUX LAP BELT STUDY   TEST NO: 1979   SUBJ ID: 95%



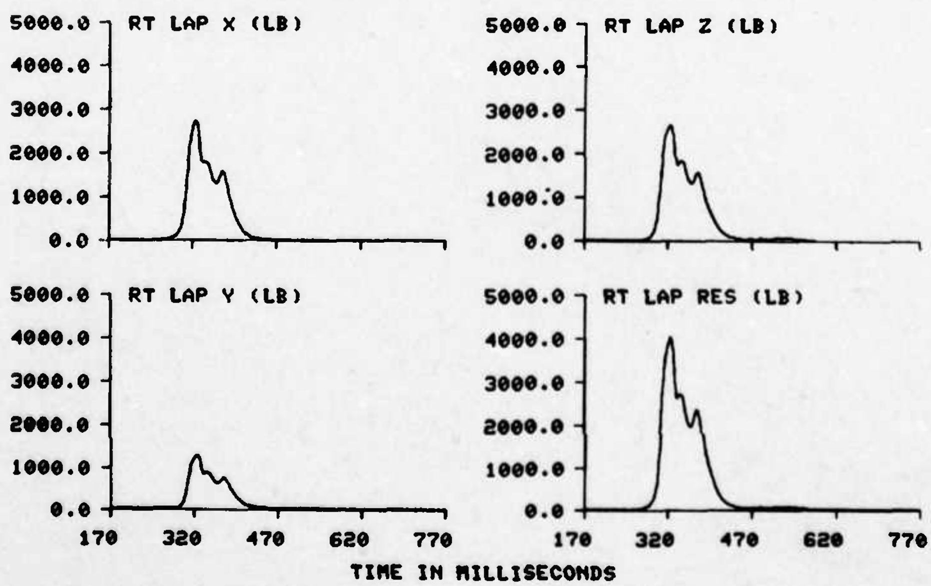
HBUX LAP BELT STUDY   TEST NO: 1979   SUBJ ID: 95%



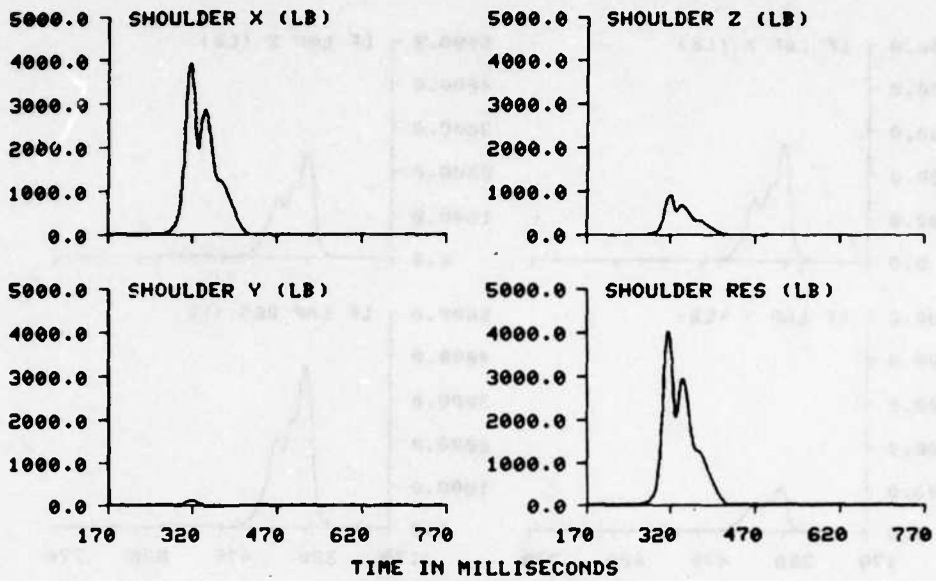
HBUX LAP BELT STUDY TEST NO: 1979 SUBJ ID: 95%



HBUX LAP BELT STUDY TEST NO: 1979 SUBJ ID: 95%



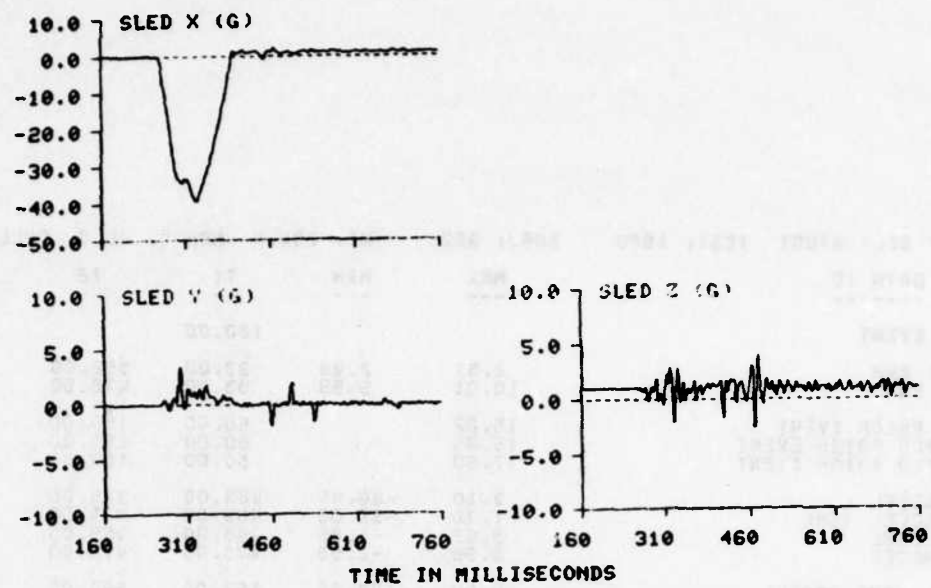
HBUX LAP BELT STUDY TEST NO: 1979 SUBJ ID: 95%



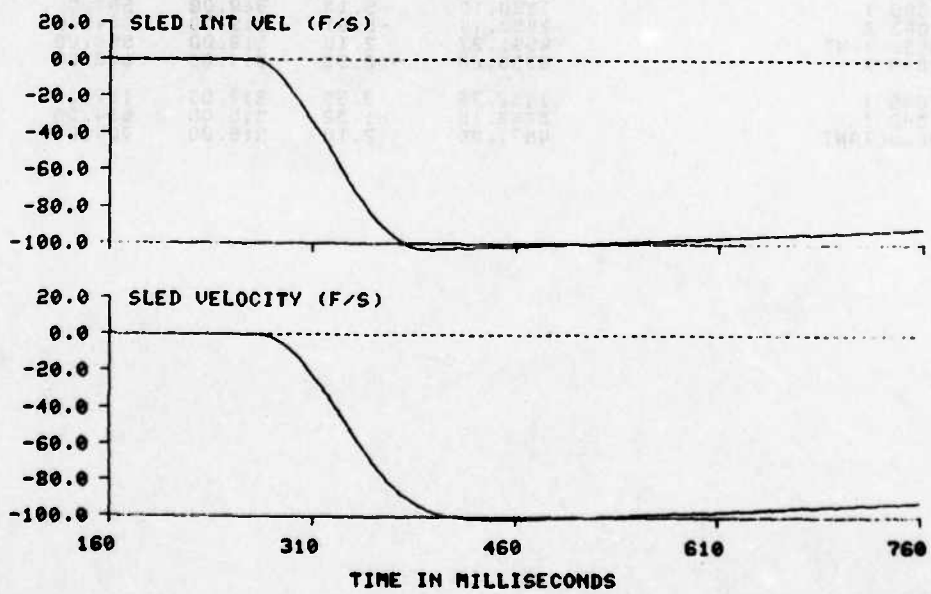
HBUX LAP BELT STUDY   TEST: 1980   SUBJ: 95%   WT: 204.0   NOM G: 40.0   CELL: X

DATA 10	MAX	MIN	T1	T2	CH
TIME OF EVENT			160.00		37
2.5V EXT PWR	2.51	2.49	93.00	352.00	47
10V EXT PWR	10.01	9.99	93.00	478.00	48
SHD PLD PRIOR EVENT	16.22		60.00	160.00	
LF LAP PLD PRIOR EVENT	18.25		60.00	160.00	
RT LAP PLD PRIOR EVENT	17.50		80.00	160.00	
SLED X ACCEL	2.10	-39.45	469.00	329.00	1
SLED X ACCEL (SM)	1.70	-39.03	469.00	329.00	
SLED Y ACCEL	3.43	-1.86	295.00	459.00	2
SLED Z ACCEL	3.99	-2.58	475.00	470.00	3
SLED VEL (INT ACCEL)	0.00	-103.23	167.00	393.00	
SLED VELOCITY	0.00	-101.53	160.00	441.00	29
VEL AT EVENT		-101.53		441.00	
SHOULDER LOAD X	4529.29	-35.81	312.00	452.00	23
SHOULDER LOAD Y	115.47	-29.93	317.00	298.00	22
SHOULDER LOAD Z	1073.88	-17.36	315.00	469.00	21
SHOULDER RESULTANT	4642.75	0.47	312.00	428.00	
SHOULDER RES / WT	22.76	0.00			
LF LAP LOAD X	3325.57	-8.10	319.00	449.00	15
LF LAP LOAD Y	1350.12	-5.13	319.00	580.00	16
LF LAP LOAD Z	2863.14	-8.91	319.00	564.00	17
LF LAP RESULTANT	4591.27	2.15	319.00	559.00	
RT LAP LOAD X	3336.80	-10.53	317.00	658.00	18
RT LAP LOAD Y	1432.79	-3.55	317.00	182.00	19
RT LAP LOAD Z	3263.10	-1.32	315.00	694.00	20
RT LAP RESULTANT	4877.86	2.10	316.00	704.00	

HBUX LAP BELT STUDY TEST NO: 1980 SUBJ ID: 95%



HBUX LAP BELT STUDY TEST NO: 1980 SUBJ ID: 95%



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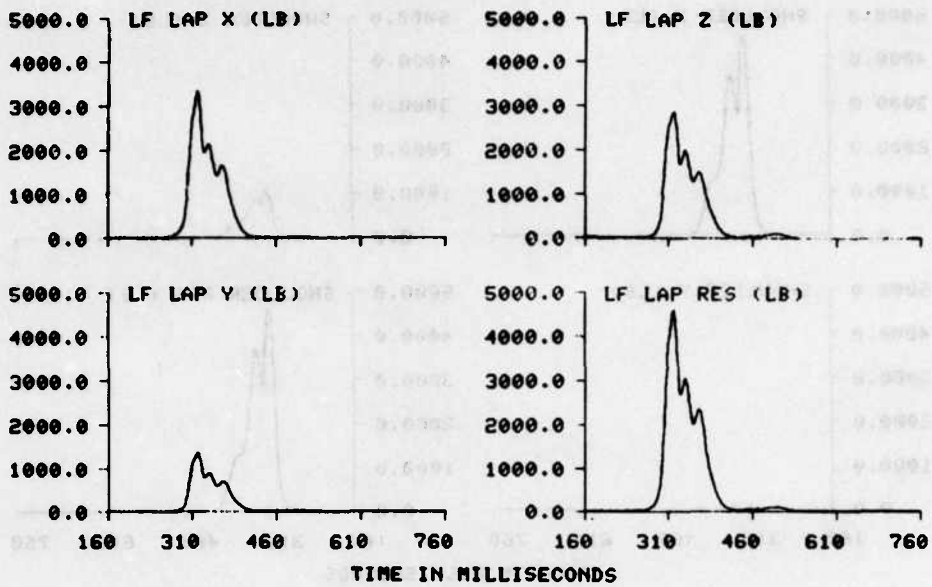
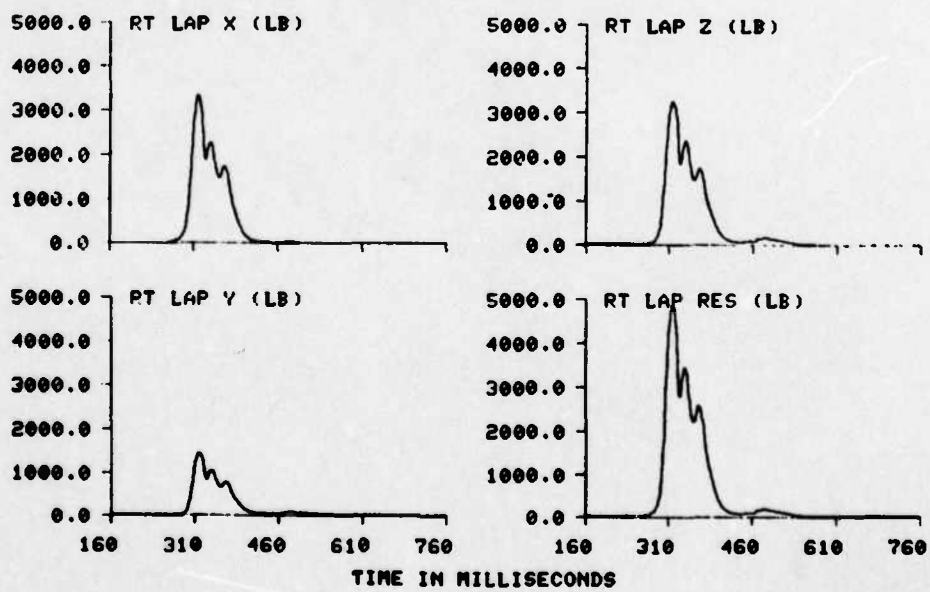
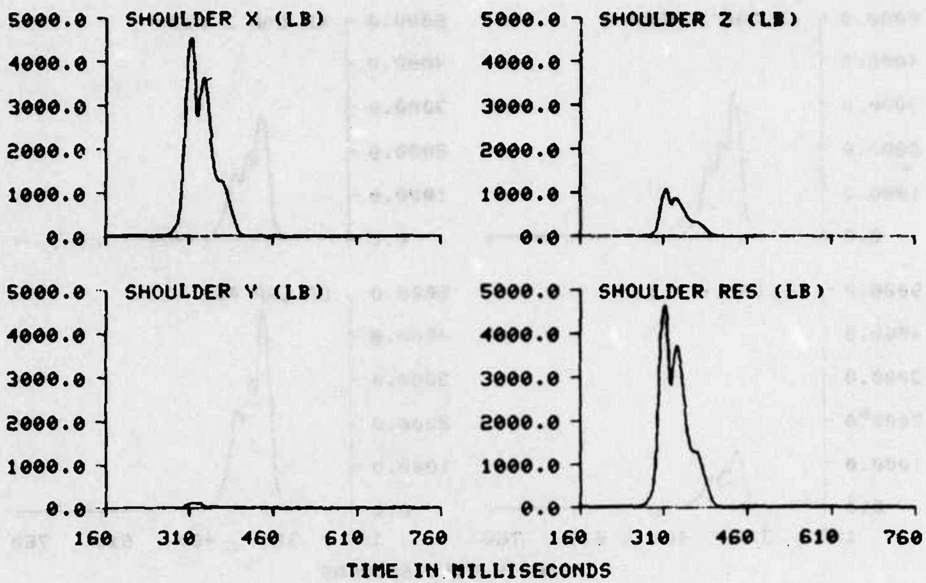


HBUX LAP BELT STUDY TEST NO: 1980 SUBJ ID: 95%



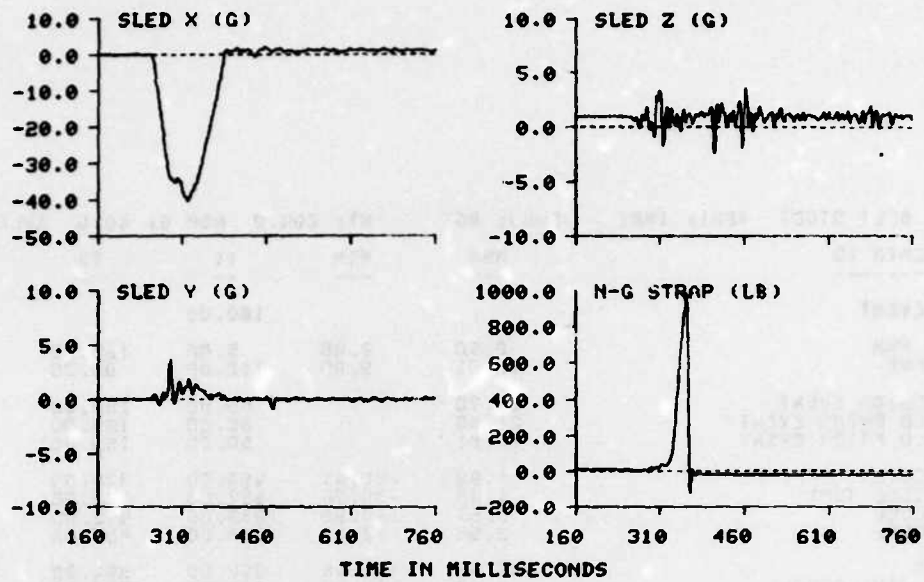
HBUX LAP BELT STUDY TEST NO: 1980 SUBJ ID: 95%



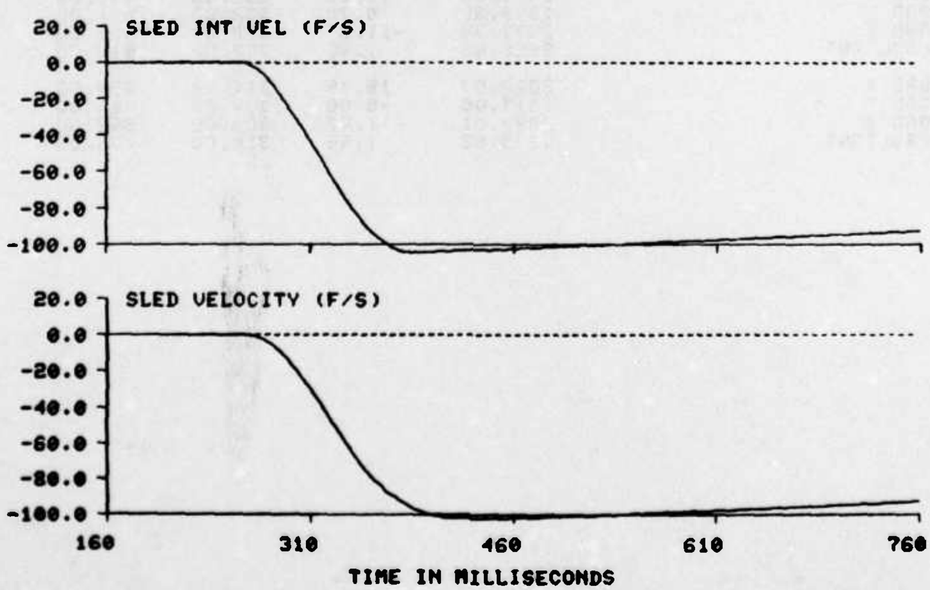
HBUX LAP BELT STUOY TEST: 1981 SUBJ: 95% WT: 204.0 NOM G: 40.0 CELL: X

OATA IO	MAX	MIN	T1	T2	CH
TIME OF EVENT			160.00		37
2.5V EXT PWR	2.50	2.49	5.00	168.00	47
10V EXT PWR	10.01	9.99	118.00	96.00	48
SHO PLO PRIOR EVENT	16.70		60.00	160.00	
LF LAP PLO PRIOR EVENT	21.40		60.00	160.00	
RT LAP PLO PRIOR EVENT	15.81		60.00	160.00	
SLEO X ACCEL	1.89	-40.41	456.00	320.00	1
SLEO X ACCEL (SM)	1.68	-39.76	457.00	320.00	
SLEO Y ACCEL	3.57	-0.93	289.00	472.00	2
SLEO Z ACCEL	3.56	-2.37	463.00	407.00	3
N-G STRAP	985.65	-124.46	358.00	364.00	30
SLEO VEL (INT ACCEL)	0.02	-104.42	236.00	385.00	
SLEO VELOCITY	0.00	-102.47	160.00	434.00	29
VEL AT EVENT		-102.47		434.00	
SHOULOER LOAD X	4402.65	-36.52	303.00	440.00	23
SHOULOER LOAO Y	272.31	-87.17	316.00	348.00	22
SHOULDER LOAD Z	1046.96	-17.31	311.00	457.00	21
SHOULOER RESULTANT	4512.40	1.12	303.00	404.00	
SHOULOER RES / WT	22.12	0.01			
LF LAP LOAO X	2527.69	-16.29	302.00	439.00	15
LF LAP LOAO Y	1049.30	-9.70	302.00	531.00	16
LF LAP LOAO Z	2427.76	-11.07	302.00	415.00	17
LF LAP RESULTANT	3658.45	1.66	302.00	410.00	
RT LAP LOAO X	3029.67	-16.15	314.00	439.00	18
RT LAP LOAO T	1317.06	-8.60	304.00	441.00	19
RT LAP LOAO Z	2922.01	-11.42	303.00	652.00	20
RT LAP RESULTANT	4378.83	1.56	314.00	426.00	

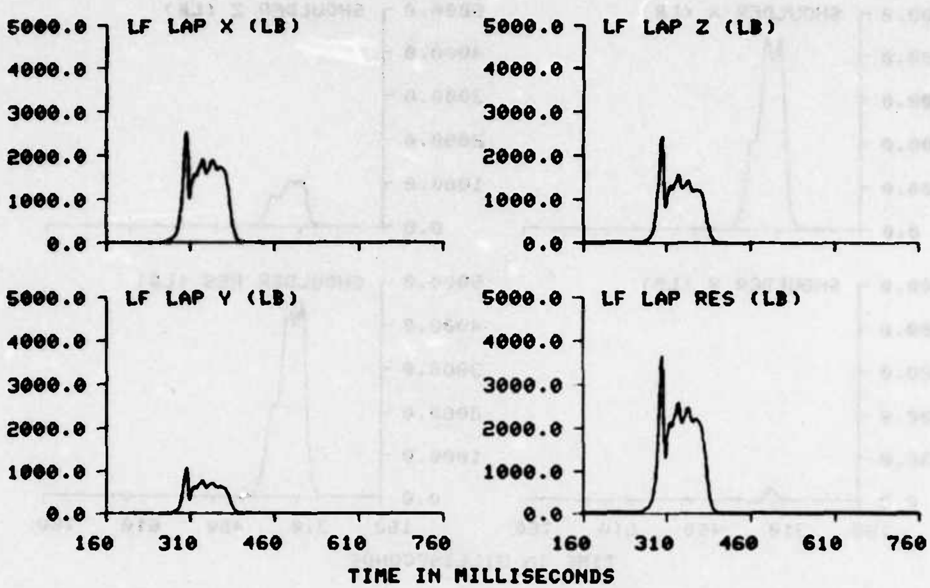
HBUX LAP BELT STUDY TEST NO: 1981 SUBJ ID: 95%



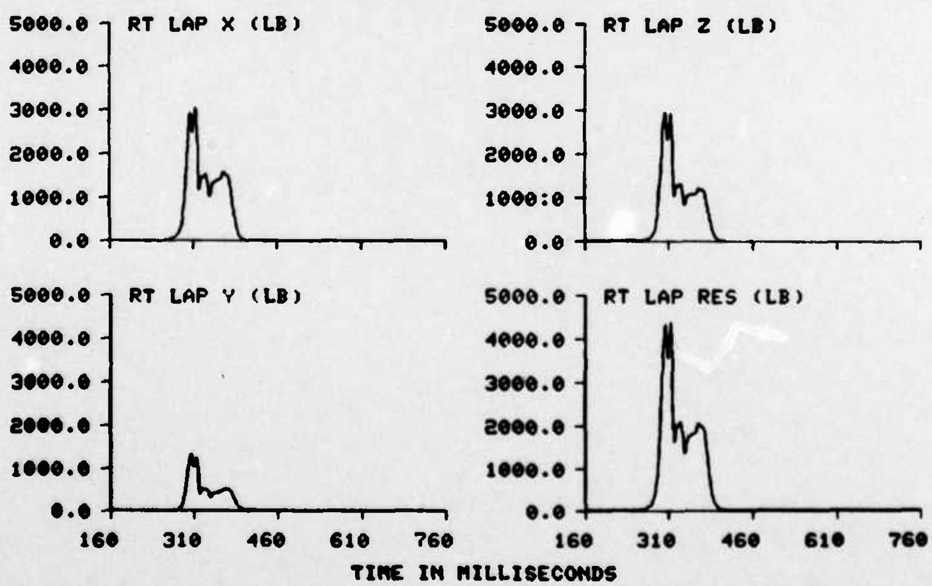
HBUX LAP BELT STUDY TEST NO: 1981 SUBJ ID: 95%

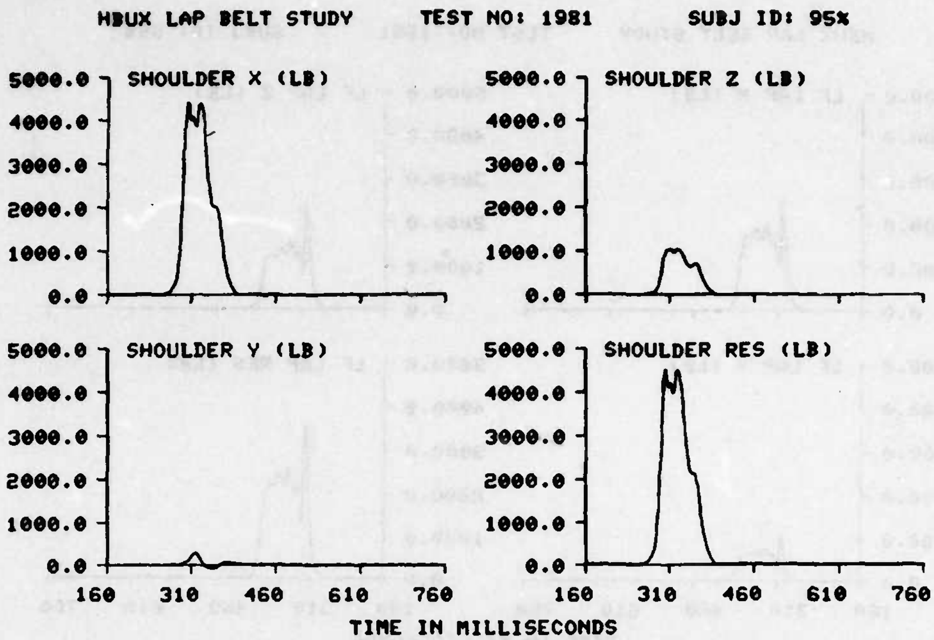


HBUX LAP BELT STUDY TEST NO: 1981 SUBJ ID: 95%



HBUX LAP BELT STUDY TEST NO: 1981 SUBJ ID: 95%

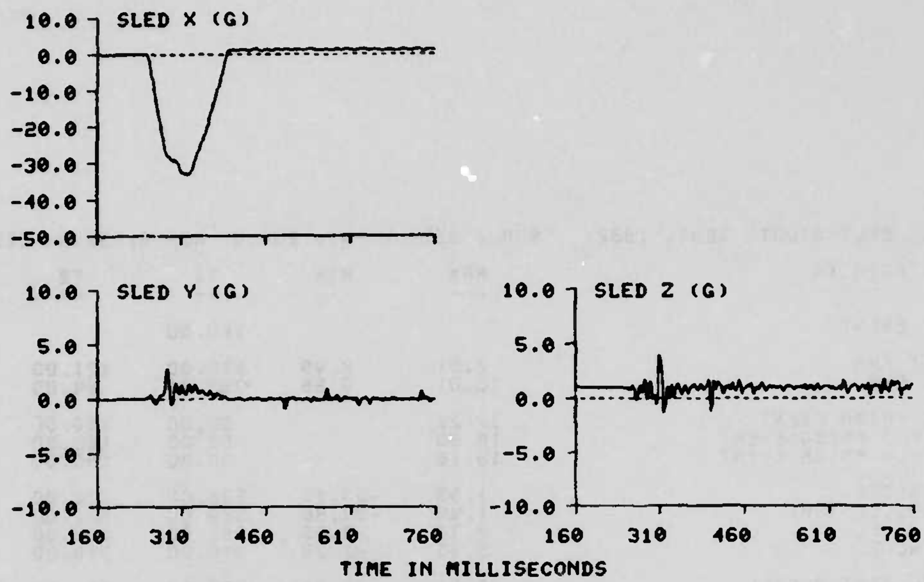



HBUX LAP BELT STUDY
TEST NO: 1981
SUBJ ID: 95%
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
160
310
460
610
760
TIME IN MILLISECONDS

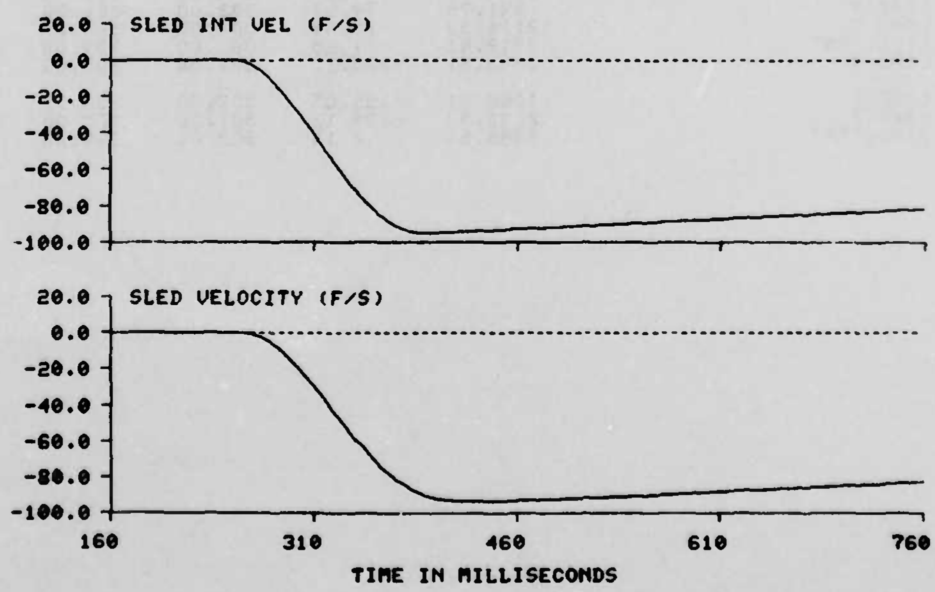
HBUX LAP BELT STUDY   TEST: 1982   SUBJ: 95%   WT: 204.0   NOM G: 32.0   CELL: X

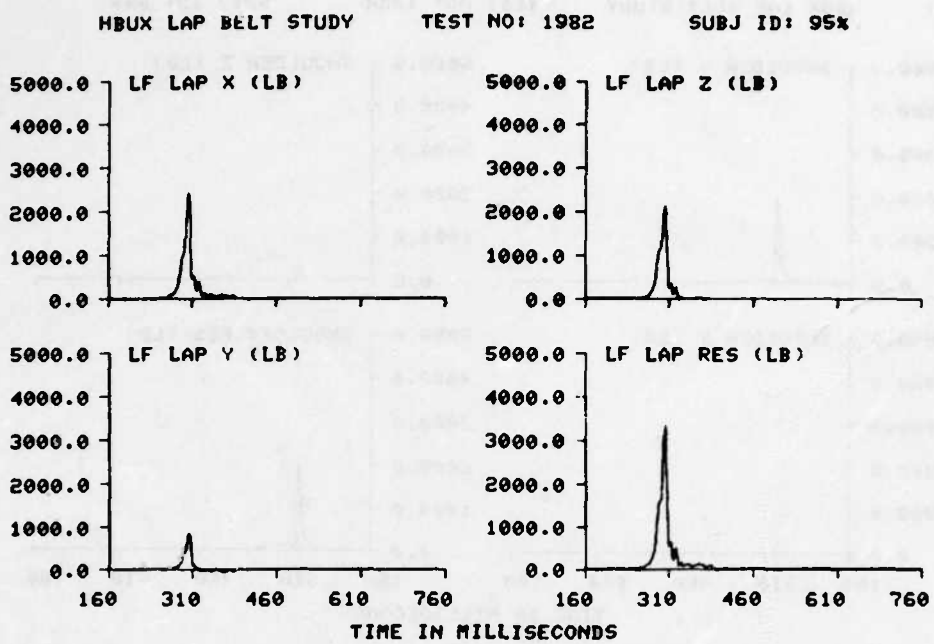
DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			160.00		37
2.5V EXT PWR	2.51	2.49	592.00	121.00	47
10V EXT PWR	10.01	9.98	283.00	24.00	48
SHD PLD PRIOR EVENT	12.22		60.00	160.00	
LF LAP PLD PRIOR EVENT	16.50		60.00	160.00	
RT LAP PLD PRIOR EVENT	19.16		60.00	160.00	
SLED X ACCEL	1.63	-33.16	586.00	322.00	1
SLED X ACCEL (SM)	1.45	-32.86	586.00	321.00	
SLED Y ACCEL	2.76	-0.95	284.00	495.00	2
SLED Z ACCEL	3.95	-1.29	310.00	318.00	3
SLED VEL (INT ACCEL)	0.01	-95.01	237.00	391.00	
SLED VELOCITY	0.00	-93.39	160.00	427.00	29
VEL AT EVENT		-93.39		427.00	
SHOULDER LOAD X	1842.53	-115.70	290.00	295.00	23
SHOULDER LOAD Y	69.81	-12.62	292.00	298.00	22
SHOULDER LOAD Z	342.04	-13.54	291.00	297.00	21
SHOULDER RESULTANT	1969.07	1.97	290.00	398.00	
SHOULDER RES / WT	9.65	0.01			
LF LAP LOAD X	2425.63	-13.39	303.00	410.00	15
LF LAP LOAD Y	841.75	-74.97	303.00	364.00	16
LF LAP LOAD Z	2116.33	-15.64	302.00	326.00	17
LF LAP RESULTANT	3318.41	1.68	303.00	757.00	
RT LAP LOAD X	2383.51	-330.13	302.00	308.00	18
RT LAP LOAD Y	1060.21	-165.05	302.00	308.00	19
RT LAP LOAD Z	2163.37	-290.12	301.00	308.00	20
RT LAP RESULTANT	3386.36	2.13	302.00	394.00	

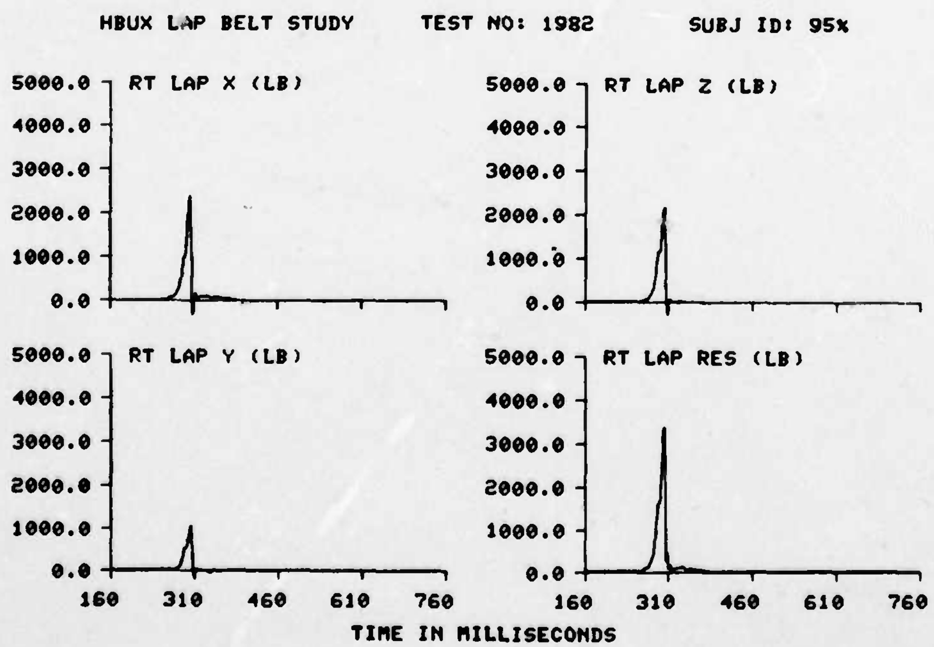
HBUX LAP BELT STUDY TEST NO: 1982 SUBJ ID: 95%

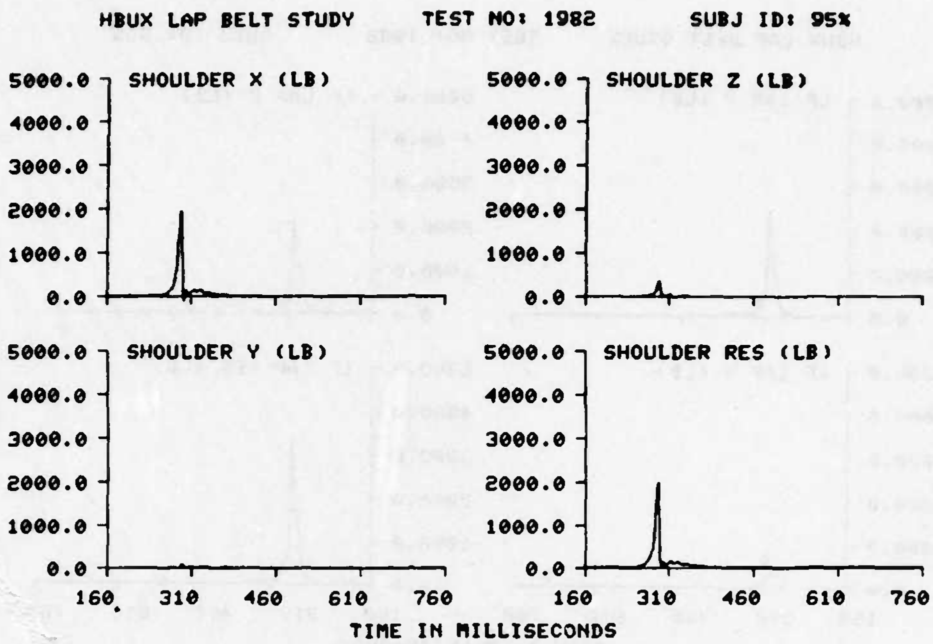


HBUX LAP BELT STUDY TEST NO: 1982 SUBJ ID: 95%




HBUX LAP BELT STUDY
TEST NO: 1982
SUBJ ID: 95%
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
160
310
460
610
760
TIME IN MILLISECONDS

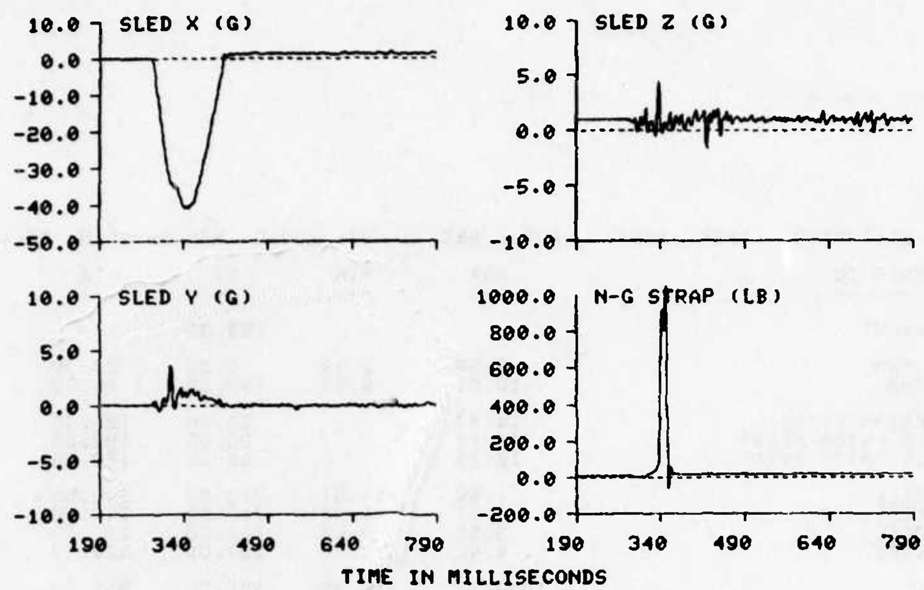

HBUX LAP BELT STUDY
TEST NO: 1982
SUBJ ID: 95%
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
160
310
460
610
760
TIME IN MILLISECONDS


HBUX LAP BELT STUDY
TEST NO: 1982
SUBJ ID: 95%
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
160
310
460
610
760
TIME IN MILLISECONDS

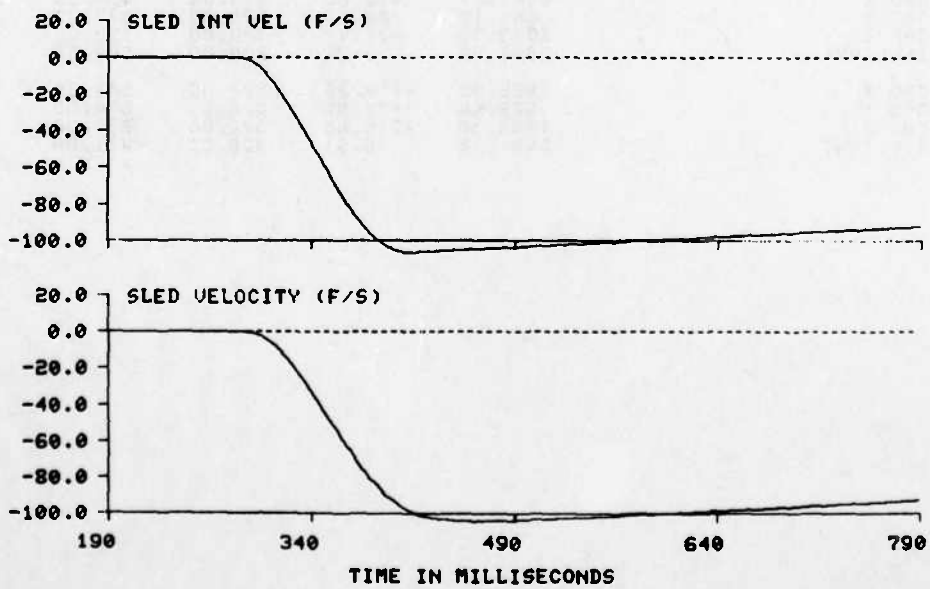
HBUX LAP BELT STUDY TEST: 1983 SUBJ: 95% WT: 204.0 NOM G: 40.0 CELL: X

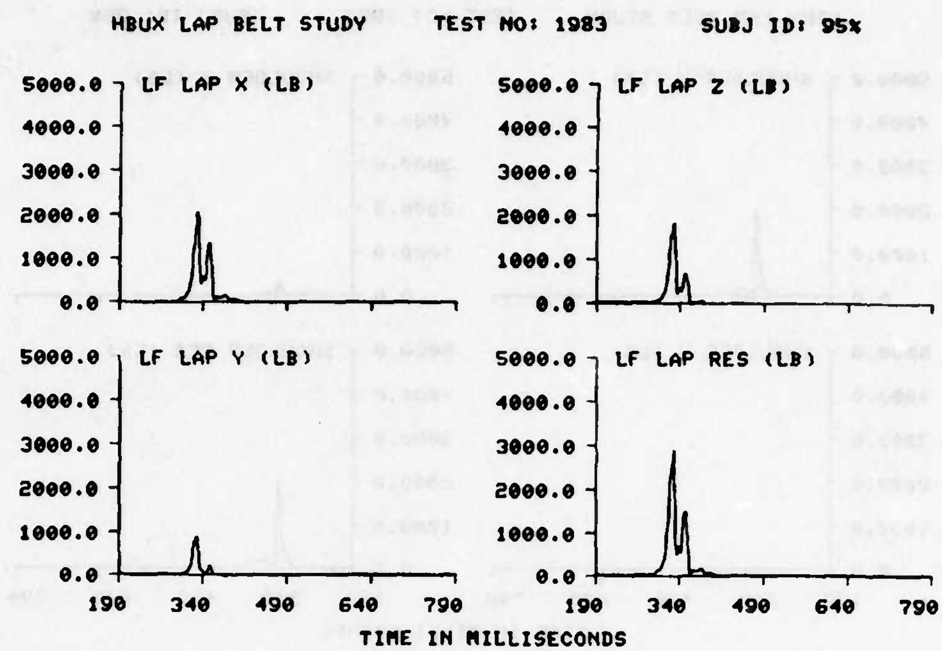
DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			192.00		37
2.5V EXT PWR	2.50	2.49	0.00	29.00	47
10V EXT PWR	10.01	9.99	142.00	54.00	48
SHO PLD PRIOR EVENT	14.97		90.00	190.00	
LF LAP PLD PRIOR EVENT	19.11		90.00	190.00	
RT LAP PLD PRIOR EVENT	18.23		90.00	190.00	
SLED X ACCEL	1.69	-41.01	710.00	348.00	1
SLED X ACCEL (SM)	1.47	-40.70	710.00	346.00	
SLED Y ACCEL	3.58	-0.48	317.00	297.00	2
SLED Z ACCEL	4.42	-1.68	337.00	423.00	3
N-G STRAP	1052.13	-56.72	349.00	355.00	30
SLED VEL (INT ACCEL)	0.02	-106.42	264.00	411.00	
SLED VELOCITY	0.00	-104.63	190.00	459.00	29
VEL AT EVENT		-104.63		459.00	
SHOULDER LOAD X	1986.84	-142.23	322.00	326.00	23
SHOULDER LOAD Y	42.13	-19.69	324.00	347.00	22
SHOULDER LOAD Z	360.04	-24.96	323.00	329.00	21
SHOULDER RESULTANT	2012.66	0.74	322.00	411.00	
SHOULDER RES / WT	9.87	0.00			
LF LAP LOAD X	2061.57	-12.60	329.00	430.00	15
LF LAP LOAD Y	884.15	-39.56	329.00	379.00	16
LF LAP LOAD Z	1823.75	-21.42	329.00	359.00	17
LF LAP RESULTANT	2891.00	2.76	329.00	502.00	
RT LAP LOAD X	1665.80	-189.29	328.00	334.00	18
RT LAP LOAD Y	529.44	-72.90	328.00	334.00	19
RT LAP LOAD Z	1646.36	-215.48	328.00	333.00	20
RT LAP RESULTANT	2401.18	0.91	328.00	431.00	

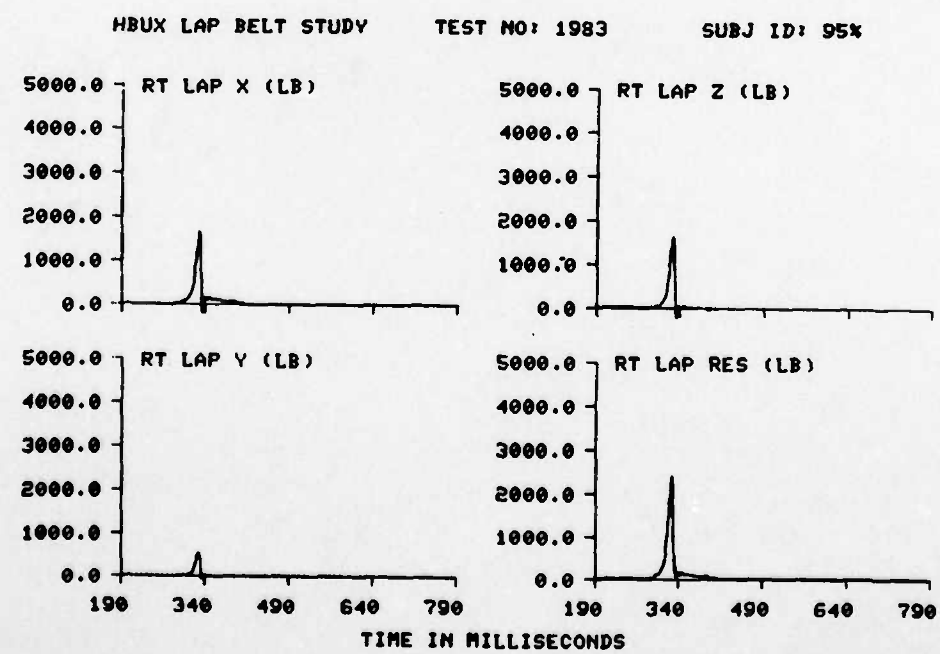
HBUX LAP BELT STUDY TEST NO: 1983 SUBJ ID: 95%



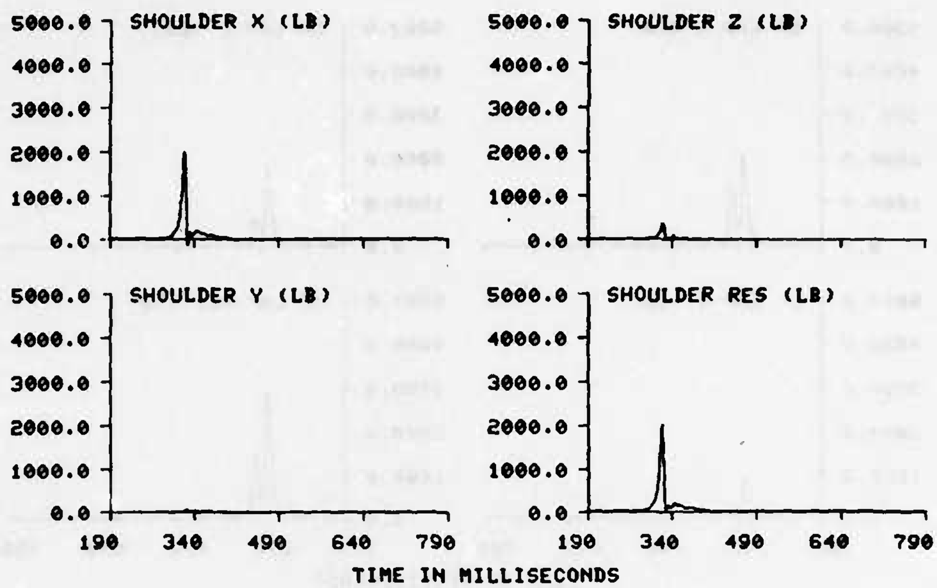
HBUX LAP BELT STUDY TEST NO: 1983 SUBJ ID: 95%




HBUX LAP BELT STUDY
TEST NO: 1983
SUBJ ID: 95%
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
190
340
490
640
790
TIME IN MILLISECONDS


HBUX LAP BELT STUDY
TEST NO: 1983
SUBJ ID: 95%
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
190
340
490
640
790
TIME IN MILLISECONDS

HBUX LAP BELT STUDY TEST NO: 1983 SUBJ ID: 95%



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